A Diary Study of Mobile Information Needs

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ABSTRACT

Being mobile influences not only the types of information people seek but also the ways they attempt to access it. Mobile contexts present challenges of changing location and social context, restricted time for information access, and the need to share attentional resources among concurrent activities. Understanding mobile information needs and associated interaction challenges is fundamental to improving designs for mobile phones and related devices. We conducted a two-week diary study to better understand mobile information needs and how they are addressed. Our study revealed that depending on the time and resources available, as well as the situational context, people use diverse and, at times, ingenious ways to obtain needed information. We summarize key findings and discuss design implications for mobile technology.

Author Keywords

Diary study, user requirements, mobile devices

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI).

INTRODUCTION

People often need information while on the go. Sometimes the information required is essential to the task at hand, such as finding a hotel for the night. Other times, the need is associated with a fleeting question prompted by a conversation or a nearby object (e.g., a billboard). Based on the importance of the need and the amount of time available, people use a variety of strategies to obtain the desired information.

Mobile phones provide increasingly convenient ways to obtain information. Internet-enabled phones give access to the mobile web, as well as personal email and calendars. Although mobile devices are becoming always connected, their limitations can be debilitating. Restricted input, small screens, and complex interfaces are particularly challenging when a person is mobile and rushed.

Many have proposed ways of transforming desktop browsing to the constrained display of mobile devices [5,7,9,12,15]. However, simply providing mobile users with access to the internet and desktop tools is insufficient. Mobile users need applications and services that are designed to the particular requirements of mobile context and use. As just one example, mobile users are often preoccupied with the things going on around them. As a consequence, they often need to decide if they have sufficient time and attentional resources to access potentially useful information services. Recently, some companies have attempted to bridge this gap with mobile content-driven services such as Google SMS, GOOG-411, Microsoft Live Mobile, and Google Mobile [1,2,3,17].

Although desktop search queries have been well studied, the mobile search space has been less adequately explored [10, 18, 19]. Kamvar and Baluja recently analyzed 1 million Google mobile search queries, finding people had different uses for mobile search vs. desktop search [11]. This is incredibly valuable data but only tells what people use search engines for, not what information needs they really had. This is further restricted by sampling only people who own devices that support such functionality. As a complement to analyzing mobile clickstream data, we need to understand what types of information people need while on the go and how they address those needs. Observing people's behaviors in such situations could point to improved mobile interface and system designs.

We report a diary study of 20 people's mobile information needs over the course of two weeks. We examined the types of information needs participants had, the strategies and methods they used to address those needs, and the contextual factors that prompted each need and influenced how it was addressed. Our study reveals that mobile contexts frequently require people to adopt novel strategies and methods. Less essential needs are often put off until later, or never addressed at all. However, needs that are essential to the task at hand are typically addressed through the perceived lowest cost method available, which is not always internet access. Based on our findings, we present several suggestions for designing future mobile technology.

METHODS

There are many methods for capturing *in situ* data from mobile users. We considered the increasingly popular Experience Sampling Method (ESM), however we felt that the

sampling frequency would need to be too high in order to capture any moment a person had an information need [12]. In contrast, diary studies allow participants to do the capturing whenever needs arise. Diary studies suffer the drawback of potentially missing data because participants forget to record entries or are selective in reporting (e.g., thinking some events are not important enough to report). Still, we chose to use a diary study because we thought it would be the most effective technique of capturing data to reveal the nature of information needs and how they unfolded in-situ. Below we describe how we managed the burden of maintaining a diary, given the detail we desired.

Participants

We recruited 20 participants (10 male, 10 female) through online mailing lists and flyers. All were required to own a mobile phone and have experience sending text messages. Ages ranged from 19-58 (mean: 30.7, SD: 10.4). We selected a diverse mix of participants including undergraduate/graduate students, human resources personnel, a financial analyst, caregivers, engineers, a homemaker, project managers, a pastor, and a temporary worker. Five of our participants used mobile internet access on their phone. The other fifteen did not have mobile internet capabilities either because their phone was not capable, or because they felt that the cost was too high.

Procedure

We asked participants to keep a diary for two weeks of all their information needs whenever they were mobile, defined as being away from home or work. Although information needs arise when at home or work, we wanted to focus on and capture those that occurred when people were mobile and away from the places where they spend most of their time. For participants with desk jobs, we asked them to record entries when they were away from their desk. We also asked participants to make entries about any information gathering just before they were mobile (*e.g.,* printing directions before leaving the house). Finally, we conducted an introductory, mid-study, and final interview with each participant, spaced 7 days apart.

Logging diary entries under mobile conditions can be especially difficult for participants. Palen proposed using voice whereby participants would dial into a voice mail system and leave a recording of their thoughts instead of writing them down [16]. This works well for unstructured responses, but for structured responses a voice menu is required which can quickly become more annoying than useful [20]. Carter and Mankoff looked at using photo, voice and tangible objects as prompts for interviews with a researcher later [8]. One of their key findings was that while these new media were more convenient, recall suffered. The txt 4 l8r system proposed by Brandt, Weiss, and Klemmer is a 'snippet'-based system whereby participants send a small piece of information via their chosen media (paper, voice, SMS, photos) *in situ*, and maintain a *post facto* web diary where they discussed their captured data [6]. The *in situ* capture was intended to provide personal data that would describe the situation sufficiently so the user could be reminded to describe it in detail in the associated web diary. In their user study, SMS was the most popular media. This approach provides some of the ecological validity of diary studies in a way that lowers the overhead associated with making diary entries.

We employed a similar 'snippet' technique to capture diary entries. We used a text messaging scheme so that participants would not have to carry an extra device or paper log to record their diary entries. We asked participants to carry their mobile phones with them at all times during the study, so they could easily use it to compose diary entries. These text messages were sent to a special email address that processed the messages and posted them on a website. We asked participants to construct their text message snippets in such a way that they would be able to subsequently answer a set of diary questions on the web. To help our busy participants remember to send in diary entries, we sent them five text messages per day – every three hours during the daytime – to remind them to record any new information needs. At the end of the day, participants logged into a website to answer six questions about their text message snippets:

1. Where were you?
2. What were you doing?
3. What was your information need?
4. I addressed the need (At the time, Later, Not at all)
5. If you attempted to address the need, how did you do so? If you didn't make an attempt, why didn't you?
6. Could you have addressed your need by looking at your personal data (*e.g.,* email, calendar, web browsing history, chat history, or other)

One concern we had was how to incentivize participation without encouraging participants to make up diary entries. We decided to reward participants for visiting the web site each night and completing the interviews, but not for constructing individual diary entries. Participants could earn a maximum of $80 throughout the study. They were paid $3/day for participation, with an extra $10 bonus incentive for participating in 12 out of the 15 days of the study. We compensated the participants $10 for the in-person introductory and final interviews, and $5 for the mid-study phone interview.

RESULTS AND DISCUSSION

Our study generated 421 diary entries, with an average of 21.1 entries per person (min:7 max:45 SD:10.5). All our participants filled in the web diary portion for any text message entries they made. During interviews we asked participants for clarification of any unclear entries. In the following sections we characterize the types of information needs people had and discuss the methods and strategies they used to address those needs. We also discuss the different contextual situations that prompted information access.

Taxonomy of Information Needs

We sorted the diary entries into 16 broad need categories based on the participants' diaries and their feedback during

interviews. Table 1 shows each category, representative examples taken from the diaries, the # of diary entries for each category (and percentage), as well as the number of participants that reported an entry in that need category.

We characterized the largest category of information needs as *trivia* (18.5%). These needs were often prompted by conversations or location-based artifacts (e.g., a billboard). They are the interesting, seemingly random thoughts that came to mind for our participants, such as *"What did Bob Marley die of, and when?"* or *"What is the nutritional benefit of eating almonds?"* Their intended use in social situations suggests, however, that they are not unimportant. When participants dismissed the need it was often because the conversation in which they were engaged had moved on to another topic, or the need was deemed not important enough within the current context.

The second highest category of need was *directions* (13.3%). *Directions* needs are ones in which participants knew where they were trying to go, but needed the address or fastest route to their destination. A related category that was also frequent was *point of interest* needs (12.4%). These are broader needs in which a person needed to first find a place of interest, and then get directions to the place. Common instances involve finding a nearby restaurant, coffee shop, gas station, or bookstore. Both categories are typical mobile information needs that can be addressed through in-car GPS/Point of Interest databases. Only one of our participants owned such an in-car system.

The *friend info* category (7.6%) includes any information about a friend or family member that can only be obtained from that specific person. For example, *"Where are Sam and Trevor?"* Three people accounted for 22/32 of the reported *friend info* needs.

Three related categories that are close in frequency are *business hours* (6.9%), *shopping* (7.1%), and *phone #* (5.7%). Although determining business hours can be part of a shopping experience, there are also times when someone might want to know business hours to obtain certain services (e.g., post office, tailor). Shopping frequently involves price checking with different stores, and trying to find the right store that sells a certain product. Phone #'s are related because they sometimes act as an intermediary need to get business hours, or find out if a product is available at a particular store. However, phone #'s can also be required to contact others.

We distinguished *personal item* (6.4%) and *schedule* (5.7%) as two separate categories because scheduling can involve both a personal and a shared schedule. Personal items are information entries that are uniquely associated with specific individuals, such as a social security number, or personal insurance policy.

Some information needs are either so predictable, or easy to access that they do not register as a need to report. For instance, traffic at specific times along a given route can be quite predictable. Weather can also be quite predictable in areas without large climate changes. Therefore, we may expect that categories such as *traffic* (4.5%), or *weather* (1.4%), as well as *sports/news/stocks* (3.8%), or *email* (2.6%) might be larger in other contexts.

Movie times (2.4%) and *Recipes* (0.7%) are often cited as highly desired mobile applications (e.g., Moviefone, Epicurious). Although they occurred with low frequency, they are still important needs. A person does not need movie times and recipes everyday, but when the need arises, it's usually important to have the information. Moreover, 9 people accounted for 10 of the movie time diary entries, and each of

Need Category	Example	% of Total Diary Entries	# of Category Entries	# of Participants Reporting Category
Trivia	"What did Bob Marley die of, and when?"	18.5%	78	17
Directions	"Directions to Sammy's Pizza"	13.3%	56	17
Point of Interest	"Where is the nearest library or bookstore?"	12.4%	52	17
Friend Info	"Where are Sam and Trevor?"	7.6%	32	8
Shopping	"How much does the Pantech phone cost on the AT&T website?"	7.1%	30	16
Business Hours	"What time does the post office close?"	6.9%	29	15
Personal Item	"What is my insurance coverage for cat scans?"	6.4%	27	12
Schedule	"Is there an open date on my family calendar?"	5.7%	24	12
Phone #	"What is the phone # for weight watchers?"	5.7%	24	13
Traffic	"How far does the traffic extend?"	4.5%	19	8
Sports/News/ Stocks	"Did the Miami Heat have any free agent acquisitions?"	3.8%	16	7
Email	"Email update for work"	2.6%	11	3
Movie Times	"Are Harry Potter tickets available tonight?"	2.4%	10	9
Weather	"What will the weather be like this weekend?"	1.4%	6	4
Travel	"Flight status of my Southwest flight"	1.0%	4	3
Recipes	"Needed ingredients for hot and sour soup"	0.7%	3	3

Table 1. Breakdown of information needs by categories. Examples for each category are from real diary entries. Categories are sorted based on their frequency in our study.

3 different people reported a recipe needs.

We identified *travel-related* items (1.0%) as a separate category because this usually involves going somewhere away from one's hometown. Travel entries included getting information about flights, hotels, or activities in the given city. Any needs associated with getting from one city to another city were placed in this category. The travel category was low though because only three people went on trips during the two-week period.

Deciding When to Address a Need
When an information need arose, our participants could have addressed the need at the time, later, or not at all. In order to determine when to address their need, they at times appeared to be calculating a complex cost function. Our data provides evidence about the factors involved in making these decisions.

Determining the Cost/Benefit of Addressing a Need
The diary entries and interviews revealed a complex set of issues that participants weighed before deciding when to address a need. These issues can be described along four dimensions: importance (i.e., value or benefit), urgency, cost, and situational context.

Important needs are those that should be addressed, even if addressing them is not required immediately. For example, *"How many units does my son have to take to be considered a student for insurance discounts?"* In this entry, our participant knew that knowing how many units her son had to take to qualify for an insurance discount would save her money. The need did not have to be addressed immediately, but addressing the need at some point was important.

Urgent needs are usually related to current activities. They are time critical and demand immediate attention. For example, participant 14 got lost on his way to attend a wedding, so his diary entry read, *"directions to the church where the wedding is being held."* Addressing this need was essential to complete his current task, getting to the wedding.

In addition to the importance and urgency of a need, our participants also considered the cost of addressing a need in terms of time and expense. When time is not critical, a person can consider multiple alternative methods to address a need. However, when a person is rushed, a method that could potentially take more time than is available isn't an effective alternative (e.g., using a cumbersome mobile browser). Participant 1, a mobile internet user, mentioned that trying to address a need with her mobile phone when she's late is not an attractive method.

"You have to type stuff in to find information which can be a pain at times depending on the circumstance that you're in. Especially when you really need it and you're going somewhere. You have to go there and you're late, the last thing you want to is be typing into your phone. You don't want to pull over on the side of the road to type things in." (Participant 1)

A particular method can also have a number of monetary costs, such as calling 411 (which costs $1.50 per/call), or accessing the mobile internet without an unlimited data plan (i.e., paying per kilobyte). One of our participants who had an internet-enabled phone rarely used it because he paid based on usage. However, in one situation he was trying to find an interesting place to visit in the nearby area with his family. After many unsuccessful attempts, he became frustrated enough to pay per kilobyte to find a point of interest.

"We were actually at a different location than we were trying to get to. We had arrived at a random museum. It was getting more and more frustrating. I pay per kilobyte, but I figured it would be worth it to pay to get this information right now. On my way back to the car I was anxiously trying to find something [online] but nothing came up." (Participant 18)

The situational context contributes to the cost of addressing a need. There are times when addressing a need may not be socially appropriate, such as during an important meeting.

"One time I was stuck in a meeting. Since it was a high profile meeting and I couldn't open my phone and text, or laptop to email. I was wondering if my team was going to be able to do this demo. I'm thinking, I need to know about this demo, but this really is an information need." (Participant 16)

People often multitask to better manage the cost/benefit tradeoffs in satisfying an urgent information need. During multitasking activities, people divide attention between the current task and trying to address their information need, creating a challenging situational context. Driving was one of the more frequent multitasking activities cited by our participants. They all acknowledged that interacting with a phone while driving is dangerous. However, 18/20 admitted to doing it occasionally, employing a variety of strategies to balance safety and the urgency of their information need. For example, participants reported trying to time their phone interaction for red lights, stop signs, or open stretches where they felt that being distracted would be less dangerous.

"Some entries I did while I was driving, and others I did at a stop sign or stop light." (Participant 1)

"I do text while I am driving. Interacting with my phone is dangerous. I try to do it while I'm at a red light or stopped somewhere." (Participant 10)

"I will wait for stop lights, or if I'm on an empty straightaway then I'll text or place a call. Or I'll write it down on a piece of paper at a stop light and then after driving I'll text it. I'll grab a scrap of paper and write it." (Participant 19)

Other participants found their needs too pressing to put off until later, and would instead use more dangerous tactics to address their information needs while driving. These participants were trying to locate their friends, obtain directions from an online map, or check their email.

Figure 1. Pie chart of diary entry percentages for when participants addressed their information need
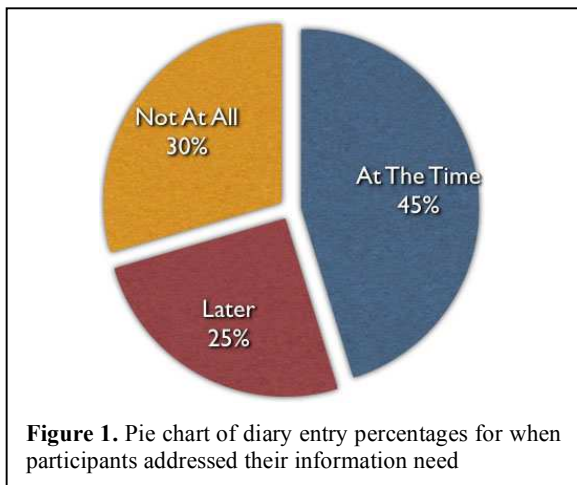
"I hold the phone (full keyboard) and then hold the steering wheel and text while driving. If there is heavy traffic I'll put it aside and then pick it up afterwards. I try to do my interaction in open stretches. I have to use my knees and elbows to hold the steering wheel while driving, but I try not to do that too often." (Participant 17)

"More than 90% of my needs were in my commute going back and forth from work and occasionally on the weekends… I try to time my texts to send them in at red lights or sitting in traffic. But I often drive with one hand and text with another. It's asking for trouble, doing too much phone interaction while driving. It's a bad habit to get into, it only takes a little lapse of concentration to get into an accident." (Participant 15)

"I try not to [enter text while driving], but I found that I've done it a few times. I almost creamed somebody doing it and then I knew that this wasn't going to work. I don't think it's a good idea. I've done it, but I don't think it's good." (Participant 20)

One way we glimpsed how participants weighted various factors in addressing an information need was by having them indicate whether they addressed their need at the time they occurred, later, or not at all. If they addressed a need at the time, we asked how they addressed it. If they did not address it at the time, we asked why they did not do so. Figure 1 shows a breakdown of when participants addressed their information needs. 45% of the diary entries showed that people addressed their needs *at the time* when the need arose. However, 55% of the entries were marked as either being addressed *later* or *not at all*. Lack of internet access was not the dominant factor, as our five mobile internet users addressed their needs at the time only 58% of the time. Below, we describe the methods participants used to address needs, and reasons they did not address needs at the time they arose.

How Needs Were Addressed At The Time They Arose
If needs were addressed at the time they arose, participants indicated the method they used to address the need. We categorized these methods into the following (Figure 2):

Figure 2. Breakdown of how needs were addressed at the time they arose across all diary entries
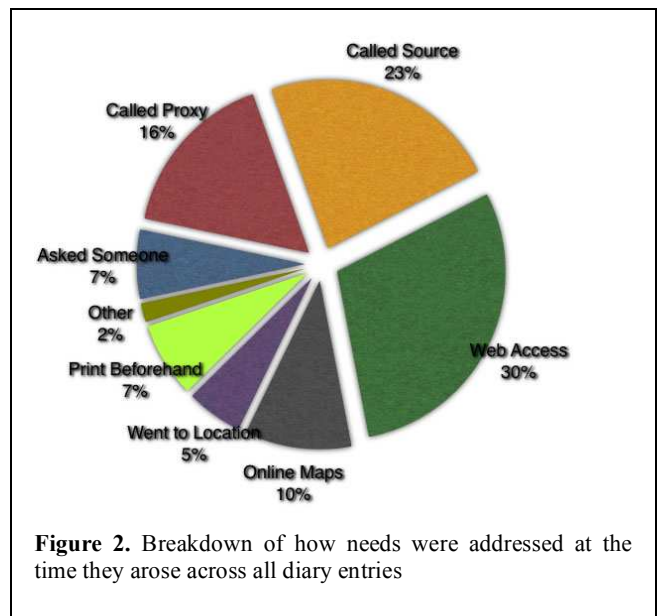
1. **Asked Someone** – Found a person and asked them face to face
2. **Called a Proxy** – Called a person/service that functioned as an indirect way to address their information need (e.g., call someone to access the internet, or call 411 to get a phone number).
3. **Called Source** – Called a service that had the desired information (e.g., call an airline company to find out flight status).
4. **Web Browser** – Accessed the web directly from a mobile device, or sought out web access at some place.
5. **Online Maps** – Used a map application such as Google Maps on a mobile phone
6. **Went to Location** – Went to a physical location to address the information need (e.g., driving to the post office to see if it was open)
7. **Print Beforehand** – Print the information before going mobile (e.g., print directions to the next location)
8. **Other Means** – Listening to the radio, looking at one's phone logs, or consulting the yellow pages.

Participants employed internet-based access 40% of the time when addressing information needs when they arose. We split internet-based access into two categories to differentiate between accessing a website and using a specific mobile application (*30% web access, 10% online maps)*. When we isolate diary entries from our five mobile internet users, 73% of their needs were addressed either through web access or an online maps application. Participants without mobile internet access employed a variety of strategies to gain internet access in order to address their needs. Sometimes a person would seek internet access at a public terminal.

Since the internet has become a main source of information access today, it is not a surprise to see people rely on it, even when mobile. Still, looking up information while mo-

bile can be difficult and cumbersome. Some of our participants printed the information they would need before they left their home or work (7%). This was commonly directions or phone numbers associated with upcoming tasks. One participant printed 22 maps to make sure he had directions for planned destinations for an upcoming trip.

Another way that participants addressed their needs was by either calling the source of the information (23%) or calling a proxy (16%) to address the information need on their behalf. Calling the source includes calling businesses for hours of operation/level of busyness (i.e., how long is the line?), Moviefone for movie times, airlines for flight status, or stock brokers for current stock market prices. Participants would often program these numbers as shortcuts into their phone when they were called frequently. An interesting alternative method was to call a proxy to address their need. Instead of attempting to call a service, participants would call a general service such as 411, or a friend/family member to access the internet for them. Some even gave out their email passwords so that the other person could retrieve information in their personal data. This proxy method was more common amongst our younger participants who usually had several people in mind who would likely be in front of a computer. Other participants felt that calling someone to look up something on the internet would be intrusive and bothersome. As a result, they would rather attempt to address the need in some other way, or not address it at the time.

As we mentioned above, circumstances can influence the method a person uses to address their need. When time is limited, a more convenient method may be chosen over other methods. Two ways that people did this were to ask someone nearby (7%), or go to a place (5%) that was the source of their information need. These two methods were chosen because at the time they were the quickest and most convenient methods available to the participants. The types of needs addressed in this way were typically direction or business hour needs.

A small number of participants addressed their need through means (2%) other than those described above. Examples include using a yellow pages book, or listening to the radio.

Why Needs Were Addressed Later
In situations where participants determined that it would be difficult to address a need, they might choose to address it at a later point in time. The three primary reasons (Figure 3) for addressing a need later were lack of internet access, being currently involved in an activity (biking/driving, busy with task, in a meeting), or realizing that the need would naturally be addressed later. We discuss each in turn.

Accessing the internet is a significant way that people address their information needs when not mobile. Since people rely on having internet access when not mobile, they naturally see it as a way to access information when they are mobile. Whether using search engines, email, or instant messaging, having internet access gives people ways to
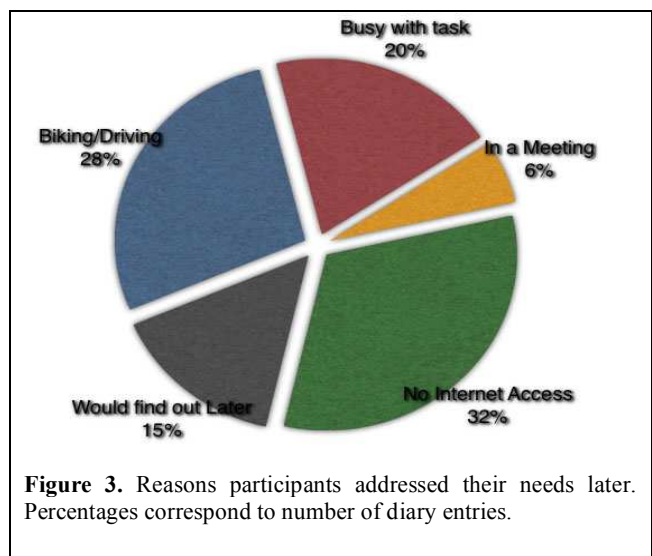

Figure 3. Reasons participants addressed their needs later. Percentages correspond to number of diary entries.

address many information needs. The top reason participants gave for deciding to address a need later, was the lack of internet access at the time (32%, a few of the mobile internet users cited not having internet access as a reason only because they left their phone somewhere else). In our interviews, 13/15 (87%) of our non-mobile internet participants felt that with mobile internet access they would be able to address a majority of their needs. However, it is important to note that the diary entries show that not having internet access only accounted for a third of the reasons a need was addressed later. This hints at there being other reasons needs are addressed later. As we describe below, many are related to the context of the current situation and the task at hand.

As depicted in Figure 3, more than half of the diary entries indicated that the reason participants addressed their needs later was because they were currently involved with an inhibiting activity. These activities included biking/driving (28%), busy with a task (20%), and in a meeting (6%). Both biking and driving are activities that require one's full attention. Despite this some participants reported addressing a need while driving. Others chose not to risk their safety and waited until later to address their need. The busy-with-task category reflects that important needs can arise while a person is doing something else, but the need is not urgent enough to "context switch" in order to address the need. Lastly, as described earlier, there are social situations where it may not be appropriate to address a need (e.g., a high profile meeting).

The last category of reasons participants gave for addressing their need later was they would "would find out later" (15%). This category involved instances in which the person knew that in the near future, another activity would address the information need. For example, one participant wanted to know the score for his favorite baseball team's game last night but was going to go see a friend soon. Instead of attempting to look up the score, he knew that his friend could tell him when they met up so he waited until

Figure 4. Reasons why needs were not addressed. Percentage of entries for each category.
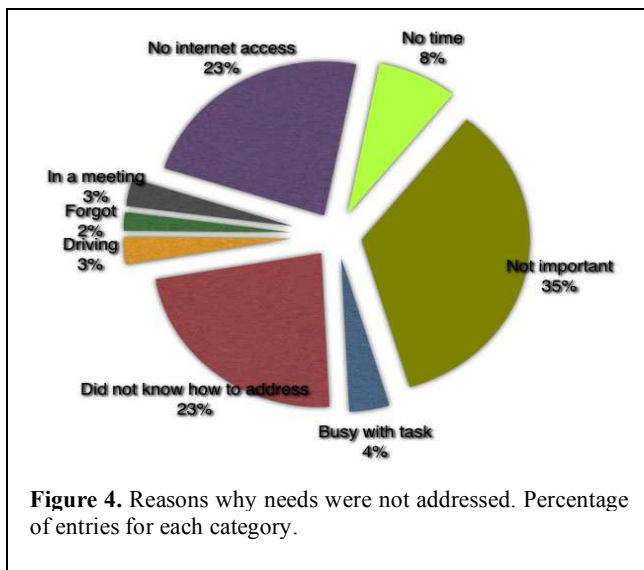
then. Participants used knowledge about future situations as one factor in determining whether a need should be addressed now or later.

Why Needs Were Not Addressed At All

30% of all diary entries indicated that the participant did not address the need at all (Figure 1). They did not attempt to address them at the time, nor did they go back to address them later. Figure 4 summarizes reports of why needs were not addressed at all. The main reason that participants gave was that the need was not important (35%). The general character of their responses was that although the information would have been nice to know when a need arose, it was not worthwhile to address it at the time. Over 40% of the "not important" entries we categorized as *trivia* needs. Other "not important" needs included business hours, shopping, weather, and points of interest.

The second highest reason that needs were not addressed was the lack of internet access (23%). Unlike the needs that were classified as not important, participants reported that these needs would have been addressed at the time if internet access had been available. However, they appear to have become less important as time passed, evidenced by them not being addressed later.

Another reason participants cited for not addressing needs was that they did not know how to address them. Even if they had available resources, they were unsure how they would have gotten the information in an easy way. One example diary entry was, *"Does the airport parking take credit card? I need to know whether to get cash or not."*

The final category of reasons needs were not addressed was that participants were engaged in other activities that prohibited them from addressing their needs. These categories included: *in a meeting* (3%), *forgot* (2%), *driving* (3%), *busy with a task* (4%), and *no time* (8%). The *no time* category includes instances when participants wanted to address the need, but they were late for their next activity. For example, participant 1 was on her way to see a counselor and

had trouble finding the address. She reported that if more time had been available she would have addressed her need through Google Maps on her phone. Instead, she relied on her knowledge of the area to find her destination.

From a design perspective, needs that are left unaddressed provide opportunities for improving future information access facilities. Satisfying even information needs that would be nice to know at the time but can be done without could possibly be enriching. An example of this came from Participant 7, who wrote, *"I wanted to watch Harry Potter tonight with my brother so I wanted to know if tickets would be available."* Unfortunately, since she was driving at the time, the need was left unaddressed and she did not end up watching the movie. If she had found out movie times, she may have been able to get tickets ahead of time, and watch the movie with her brother.

How Does Mobile Internet Change Behavior?

Throughout our discussion, we have not made a strong distinction between participants who had mobile internet access and those who did not. As mentioned earlier, 13 out of the 15 participants (87%) who did not have mobile internet access felt that with it, they would have been able to address a majority of their information needs. However, all 5 participants who had mobile internet access felt that it was not adequate for addressing their information needs. We noticed two characteristics of mobile internet usage that demonstrate how having unlimited mobile internet access can change behavior. The responses from the mobile internet users also capture how it was inadequate for addressing all their information needs, due often to their situational context and current activities.

First, we found that internet users appreciated being able to address their needs on their own without having to call someone for assistance. Several of our participants without mobile internet would call a friend to lookup information on the internet. However, the mobile internet participants would open their web browser, or mapping application to obtain the information directly.

"I find it more convenient to search it myself. Explaining on the phone… some people just don't get it when I explain something." (Participant 3)

Second, all 5 of our mobile internet users were quite savvy with their phones, for example employing shortcut techniques to obtain information quickly. Participant 1, who uses a Blackberry Pearl (pseudo-qwerty keypad) said:

"I have shortcuts, so it's almost like a qwerty keyboard. I usually type really fast. Restaurant took about 30 seconds. It's a traditional website that you have to scroll down to see wherever you need to go." (Participant 1)

This participant had several shortcuts to common web resources that she uses to obtain information. These shortcuts help speed up her workflow, but mainly tended to work for simple information queries. In addition to having bookmark shortcuts, one participant wanted to avoid launching a web

browser and would prefer a more integrated phone-based application. He said,

"I wish my mobile phone had a built in Superpages, so I don't have to go to the web, launch Google, and type something in to an obscure system. I wish Superpages was integrated into the phone. Similar to how Google maps is integrated into my phone." (Participant 3)

Despite the mobile internet being a useful tool, all mobile internet participants alluded to it not being sufficient. Either the interaction was too cumbersome or their circumstances prohibited them from using the internet due to the extensive interaction required. Two participants described their frustration with accessing the mobile internet, one due to limited time, the other because of the cumbersome interaction.

"You have to type stuff in to find information which can be a pain depending on the circumstance that you're in. Especially when you really need it and you're going somewhere. You have to go there and you're late, the last thing you want to do is be typing into your phone." (Participant 1)

"The website was too much information. I just wanted to know the park hours and I got the whole water department. I said forget it. Google search turned up a few hits. That was the #1 hit. The top few were related to that same website. I figured that website was going to give me the information I needed, so I browsed for a while. Too much information so I gave up. I gave up after not too long. I spent maybe 3-4 minutes." (Participant 15)

The mobile internet has certainly changed the way people address their information needs. As our data indicates there are also many opportunities for improvement. However, even with better forms of interaction and increased bandwidth, users still confront issues of limited attentional resources as well as challenging contextual and situational factors.
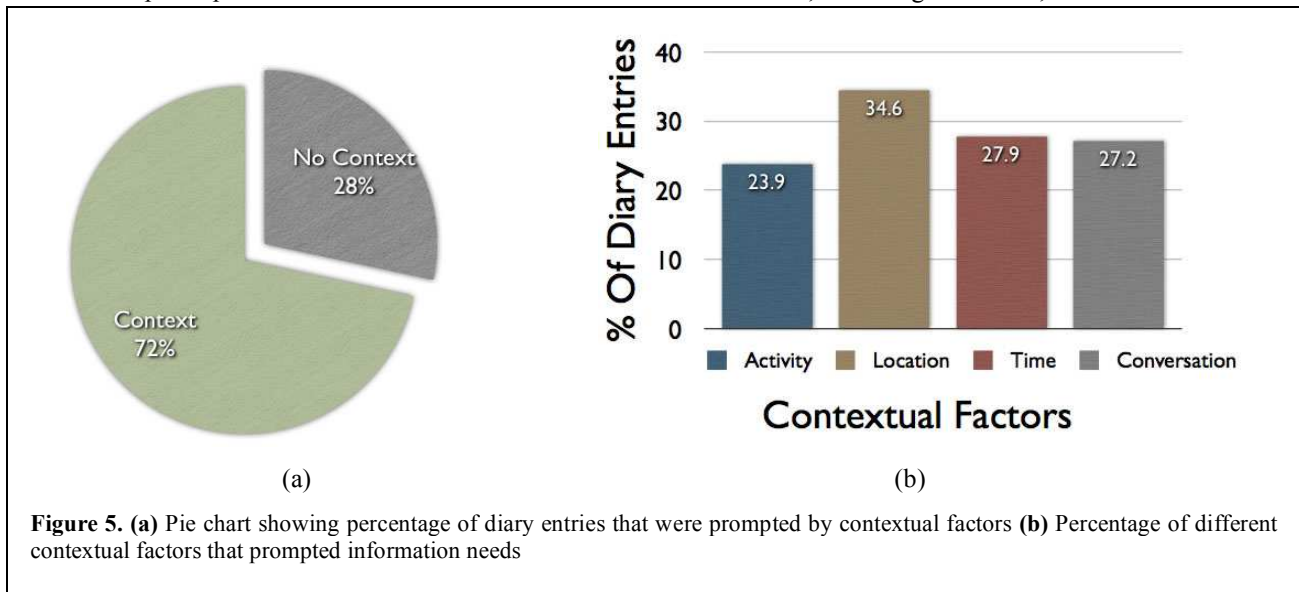
What Prompts Information Needs?

Given that our participants were unable to address information needs 55% of the time (Figure 1), and frequently experienced frustration, we wanted to explore how exploiting context might alleviate some of these problems. One participant said, *"On my own life, it seems so much of my needs are specific to the context."* Context-aware computing promises improved information access and more opportunistic information delivery. Mobile context-aware applications have typically been designed for one specific purpose, such as a friend finder, or shopping assistant. Since context can heavily influence when needs arise and how a person might address their needs, we examined diary entries to better understand the context that prompted the need in each situation. Our analysis is based on entries in which participants either indicated what prompted the need in their entry, or provided clarification in the interviews.

Participants indicated that 72% of their reported information needs were prompted by some contextual factor (Figure 5a). The contextual prompting can be classified in four broad categories: Activity, Location, Time, and Conversation (Figure 5b). Activities reflect what the person was doing at the time. Location is the place where the person was at and includes any additional artifacts at that specific location. Time is the time when the need arose, and conversation is any phone or in-person conversation the participant was involved in at the time. Some diary entries were related to multiple aspects of context, such as having a conversation with someone about artifacts at the current location.

Mobile context research in the past decade has focused heavily on location acquisition [13]. With location being the most widely cited prompt for mobile information needs (34.6%), the possibility of applying the results of these research efforts is encouraging. Recent projects have begun to deploy location-based systems on mobile phones, making the technology widely available for use. There are several additional areas where context might be useful. Activity recognition can help provide a person with information related to their current task. For example, real-time traffic information, nearest gas stations, and directions could ap-

(a)　　　　　　　　　　　　　　　　(b)

Figure 5. (a) Pie chart showing percentage of diary entries that were prompted by contextual factors **(b)** Percentage of different contextual factors that prompted information needs

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pear while driving. Time is a heavily used form of context that helps people plan their day-to-day activities. A person's calendar can help determine what types of information needs a person may have. The last form of context that prompted many information needs was conversations. We separated conversations from activities because a significant number of diary entries indicated that a participant's information need arose because of something another person mentioned.

Where Does The Information Come From?

Regardless of whether a need was addressed or not, our participants indicated whether they could have found the information by accessing a public, personal, or physical data source. A public data source can be accessed by anyone (e.g., the web). A personal data source is accessible only by that person (e.g., email, web history). A physical data source can only be accessed through physical methods and not electronically. Understanding which data sources are frequently helpful for addressing information needs can guide the development of further mobile technology.

Public data was the most commonly cited source (58%) for addressing information needs. This is congruent with how our participants associated addressing their information needs with internet access. While public data provides a large sphere of helpful information, personal data was also a significant source for information access. Many of these needs were solely personal (24%, e.g., access to calendar), however a common strategy was to first pull information from a personal data source (14%, e.g., an address from email or contacts) and then use that as a pointer into or retrieval key on a public resource (e.g., using the address to pull up a map). Although such use of personal information is vital to completing the task, it also entails a two-step retrieval process, often complicating the task.

Interestingly, 4% of the information needs indicated that they could *only* be addressed by visiting a place itself, at least using prevailing technologies (e.g., "*Is the line long at Rubio's*").

DESIGN IMPLICATIONS

Many needs in our study were addressed by awkward methods or at a later time due to limited attentional resources being available or other situational factors Based on these observations, we offer several design suggestions for ways future mobile technology might better address mobile information needs.

First, mobile technology should take into account a person's current task and enable ways to address needs at later more convenient times. More than half of our diary entries indicated that people were unable to address their need at the time it arose due to their current activity. Mobile technology that is sensitive to this could help people address their needs when situations change and resources are more freely available. Few current mobile applications are sensitive to use in multitasking situations or provide mechanisms

to conveniently record needs when they arise in ways that support them being satisfied in the future.

Second, a person's context significantly influences their information needs. 72% of diary entries involved information needs that were triggered by context. As we discussed earlier, the contexts included activity, time, location, and conversations. Designing technology that considers these aspects of context could aid in providing people the information they want at the "right" time and in a form appropriate to the current context.

Finally, satisfying 38% (28% solely personal, 14% indirectly to a public resource) of our participants' information needs involved access to their personal data, obtained either through web-based services or their personal devices. The personal data source often acted as a pointer to retrieve a public resource. This suggests that better access to these personal data sources as well as easy transitions between personal/public sources is an important opportunity to explore. Current mobile technology requires a person to first access a personal source in one step, and then another step to access the public resource. Seamless connections between the two could ease the burden when addressing their information needs.

These three dimensions help specify a design space for future tools to facilitate mobile information access. Our data suggest that future systems should take into account a person's context as well as their personal data stored across multiple devices to better service their mobile information needs. Such systems could be similar to recommender systems, but we envision a broader, more personalized system that would reduce the burden of mobile interaction and be sensitive to users' contexts during periods of limited attention (e.g., driving).

Designing such a system is challenging because context-based information systems have the potential to become nuisances if they misidentify the context. People are also concerned that context-based systems might enable unwanted personalized advertising and other forms of spam, and myriad privacy issues must be confronted (e.g., who has access to the system, where is data stored and how is it protected). To better support mobile information access these and many additional challenging issues need to be addressed.

We asked our participants about how they would feel about a tool that could predict their information needs and provide appropriate information at the "right" time. 17 participants responded positively to the idea.

"That'd be really cool. Especially you wouldn't have to type it in and look it up when you are on the road."

"That'd be interesting. If it relied on some sort of system where you used time and GPS so it could tell where you are. If you are at the zoo, you could check out such and such. I don't think that much of a hindrance. It might actu-

ally be pretty cool. .... I also don't think it'd be on the mark all the time"

"I can definitely see some advantages to that. If I look at the maps on my phone like google maps or traffic then I have to get to the map and wait for it to load. Or I have to dial a phone call can be a hassle. So I can definitely see an advantage to that."

"I would be impressed by such a system. Definitely. I guess if there was software that knew your daily routine and gave you traffic information on your way home. Yea, I would have found such a system useful. A lot of the information needs are random, so you can't predict them. For the regular ones though yea it would have been helpful."

Our other 3 participants were more hesitant, mainly concerned with privacy and control issues. Although they use services that currently search through their private data, the thought of additional loss of control made them uncomfortable.

"On the one hand I think it's convenient, but on the other hand I see it as disconcerting because my technology is becoming too smart. I worry that there is a possibility for over policing of my needs. I don't want to be manipulated."

"I would find it annoying. I guess I would find it violating to my privacy. I don't even like it when Gmail searches your email account and things pop up on the side."

CONCLUSION
In our two-week diary study we found that people on the go have a panoply of information needs, as well as challenging constraints in addressing them. We also found that people employ an ingenious variety of methods to satisfy information needs in a timely and situationally appropriate manner. Many information needs were postponed or unaddressed because of attentional costs and contextual factors. An important note is that lack of mobile internet access was not the only inhibitor by far. Even those with mobile internet access employed a wide variety of methods, and still they only addressed their needs 58% of the time, meaning that 42% of the time they postponed or never addressed their needs. A device's sensitivity to the task at hand, situational context, and the links between personal and public data holds promise to ease mobile information access by providing the right information, at the right time, and in the right form for the current context. In addition, there is promise in enabling convenient capture of needs at the time they arise so that they might be satisfied at more appropriate times in the future.

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