Undistracted Driving: A Mobile Phone that Doesn't Distract

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ABSTRACT

Distracted driving is a major problem that leads to unnecessary accidents and human casualties everywhere in the world. The ubiquity of mobile phones is one cause of distracted driving. In United States alone, operating mobile phones while driving has been cited as a factor in crashes that have led to 995 deaths and 24,000 injuries in 2009. To mitigate the problem of distracted driving caused by mobile phones, we propose using *context-awareness* to implement *burden-shifting*, *time-shifting*, and *activity-based sharing*. Although the first two concepts have been introduced before in the research literature and the latter two are novel, none of these concepts have yet been explored in the context of mobile phones and driving. We present our initial interaction designs for these concepts on the Android platform.

Categories and Subject Descriptors

H.5m [**Information Interfaces and Presentation (e.g., HCI)**]: Miscellaneous; K.4.0 [**Computers and Society**]: General

General Terms

Design, Human Factors

Keywords

distracted driving, mobile phones, human interruptibility, context-aware communications

1. INTRODUCTION

Today, a mobile phone user is reachable virtually any time and any place. While there are many benefits in being connected all the time, it can also lead to interruptions at undesirable times. In some cases, these interruptions are inconvenient, such as when in a meeting, but in other cases they can be dangerous, such as when driving. For example, during a typical daylight moment in the US in 2009, 9% of all drivers were using a hand-held or hands-free phone while driving [29]. Using mobile phones while driving in the United States has been indicated [28] as a factor in crashes that have led to 995 deaths (in 867 crashes, 18% of all fatal distracted-driving crashes) and 24,000 injuries (5% of all people injured in crashes) during the year 2009. It is not surprising that a body of research [22, 4, 3, 28, 29] has shown how using mobile phones distracts the driver from their primary task of driving. Due to this extensive research, many states [12] in the US have banned texting or using hand-held phones while driving, while the federal government has banned truck drivers from texting [27].

We observe that people need and want to use their mobile phones even while driving [25], for example, to coordinate meetings or communicate directions. Towards this end, mobile phone and car manufactures have designed various hands-free systems utilizing e.g. Bluetooth and voice-control. Unfortunately, research has indicated [4] that even if the mobile phone is operated hands-free, it can nevertheless distract the driver and may therefore cause crashes. We also note that with today's mobile phones, the caller does not know what the person who they are trying to call is doing, for example, are they driving or not. On the other hand, sometimes it is important to be interrupted, for example if there is something urgent related to work or during a family emergency. Our observation is that some of these interruptions introduced by a mobile phone while driving could be deferred or resolved in other ways.

To address the problems outlined above, we propose four techniques that reduce the need to operate a mobile phone while driving. Our approach is to leverage *context-awareness*, such as location and movement of the call recipient, and the identity of the caller to implement *burden-shifting*, *time-shifting*, and *activity-based sharing*. This information can be used to 1) give callers appropriate information about recipients' context without recipients actually needing to answer the phone, 2) let callers communicate with recipients when the situation is appropriate, 3) respond automatically when possible, 4) defer messages and send pre-planned messages, and 5) share estimated arrival time. In designing these approaches, we need to balance multiple conflicting requirements: the new system should be easy to use and configure, establish more efficient communication, substantially reduce undesired interruptions, be privacy sensitive, and interrupt the driver when the situation demands it. In the rest of this paper, we further motivate our approach, present our design and contrast it to related work, and discuss engineering and implementation issues and limitations.

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HotMobile'11 March 1-2, 2011, Phoenix, Arizona, USA.
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2. MOTIVATION

To further motivate our approach, we discuss a common scenario that can involve driving and using a mobile phone: picking up a friend with your car. With ubiquity of mobile phones, it is common that people are flexible when scheduling meetings and such [16]. For example, without our proposed system, we can imagine people agreeing "I'll call when I'm near your apartment so you'll know when to come out." Arranging for a pickup can involve the following steps 1) negotiating the (approximate) time, 2) informing the person to be picked up that the driver is leaving or on the way, and 3) informing that that person that the driver is nearby or at the pickup location. Alternatively to 3), sometimes the person waiting for the pickup might get anxious where the driver is and 4) call the driver, and the driver might be stuck in the traffic and 5) call to inform of late arrival.

We use this scenario to illustrate the key concepts we utilize in this paper: burden-shifting (BU), context-awareness (CA), time-shifting (TS) and activity-based sharing (AB). Bob calls Alice whether she could pick him up when she leaves work. Alice agrees with Bob that she'll pick him up around 6 PM. After the call has finished, Alice is presented with an *after-call interface* where she chooses the option "schedule a pickup" (TS). She also chooses to share her estimated-time-to-arrive (ETA) with Bob near the time of the pickup time (CA, AB, TS).

Alice is exiting the parking lot of her work place, and her phone sends an SMS to Bob that Alice is on her way (CA). Bob reads the message and thinks that he has probably plenty of time to get ready since it takes usually on hour for Alice to get to his house.

Alice is stuck in traffic and her phone estimates that she will not be at the pickup location at 6 PM. The phone sends a SMS to Bob indicating that Alice is likely to be a bit late because she seems to be stuck in traffic since she is driving very slowly (CA, BU).

Alice starts moving again on the highway. Her friend Carol is thinking about calling Alice and picks up her phone. Looking at the contact list, Carol sees immediately that Alice is driving, and decides not to call her but just send her a text message (CA, BU). Alice's phone receives the text message, but it does not alert Alice because Alice is driving (TS). Also, telemarketer Eve has decided to call Alice. Because she is not in Alice's trusted contact list, she will receive no information about Alice, except that her call is directed to voice mail automatically.

Alice is finally within 2 miles of Bob's apartment and her phone calls Bob that she will be arriving shortly. Bob also checks the contact list and indeed it shows that Alice's ETA is five minutes (CA). Bob hurries downstairs and finds Alice waiting for him at the parking lot. Meanwhile since Alice has parked, her phone alerts her that she has received a text message and voicemail (TS).

3. DESIGN

Based on related work, surveys we administrated (we omit reporting them due to space limitations), and analysis of the design space, we concluded that the mobile phone user experience during driving should be: *nothing seems to happen at all unless there is an emergency.* However, before we start to discuss our design, we discuss a strawman approach first.

Strawman Approach We might assume that the users would always just put their phones offline or on silent. This approach will not work robustly because people already forget to put their phones on silent when they e.g. go to meetings. And even if they put the phone on silent, they can forget to put the phones back to normal mode. Further, as our motivation section already highlighted, there are mobile information needs that are not addressed by merely turning a phone to silent mode.

Context-Awareness We consider two perspectives of context-awareness: systems and human. In our approach, the context-aware system, which is implemented using the sensors and other data available on the mobile phone, is used both to give contextual cues to potential callers, and also to implement the other novel concepts we discuss in detail below.

Previous studies have shown [18] that merely presenting context information about users might not be enough to nudge users to defer calling in inappropriate moments; accordingly people might not even view detailed context information before placing a call. We further note that even if people are presented with appropriate context, there is a mismatch between what call recipients and callers consider to be a worthwhile interruption [1].

Burden-shifting shifts the burden of call management to the caller who is not driving. The approach nudges and pushes the callers to defer communications with the help of context-awareness.

Building on previous work, we designed that the basic context information shown to the user should be simple: available, busy and unknown status (e.g. if status information is not shared), in addition to hints about the reason for this, e.g. icon for driving. In contrast to previous work, the actual status and desired contact methods are *pushed* to the caller. This way, we shift the burden of call management to the caller.

When the user decides to place a call to a person, they can usually dial a number directly or, more commonly today, choose the intended recipient from the contact list or the missed calls list. In our approach, we present information similarly to Calls.calm [19] where users are presented with a dialog when they decide to call a person. We will next discuss the user interface and interaction design for the case in which the intended call recipient is driving. We assume that both parties are "trusted contacts" as discussed later. In the following discussion we will use the word *caller* to denote the person who is initiating a contact and *call recipient* the person who is the intended recipient for a contact attempt, whether it is a call, text message or other means.

Simple Context Information The contact list (see Figure 1) shows the name and status of "driving". When a caller chooses a contact from the list, the caller is presented with the following options:

- Send a text message (time-shifting)
- Voicemail (time-shifting)
- Call only in emergency
- Setup reminder to call again (burden-shifting)
- Share your status with [the contact]

If the caller decides to send a text message, they can proceed normally. After finishing writing a text message, the

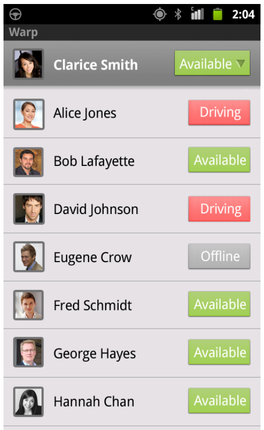

Figure 1: Snapshot of Simple Context Information in the Contact List: Alice and David are driving, Eugene is offline, and others are available.

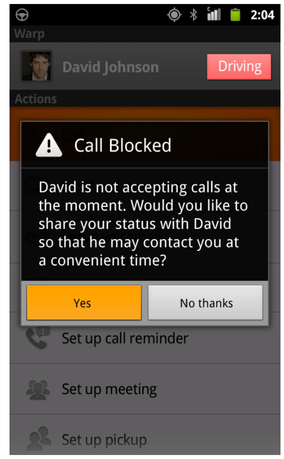

Figure 2: David is not accepting calls and the phone prompts to share status with him.

caller will be told that "your message will be delivered after the person has stopped driving". This way, there is no need for automatic replies from the recipient's phone, and further, the caller knows not to wait for an answer until the person has stopped driving. Similarly, the caller can opt to just call voicemail directly, and the recipient will be notified of the voicemail after having stopped driving.

The "call only if emergency option" verifies with a dialog "Is this emergency? (Yes / No)" before attempting a call. If the caller chooses yes, the dialog will show that "you are placing an urgent call, please hold on the line while the driver finds a safe place to park and answer the phone". This would cause the recipient's phone to start ringing and speaking "urgent call from [name], please park safely before answering". The motivation for this option is, that according to our surveys, people desire to be able to receive urgent calls from trusted people even if otherwise everything would be deferred later. Further, this simple design allows the driver to find a safe place to stop and answer the call.

One more example of burden-shifting is the "setup a reminder to call again" option in the call management interface. Instead of just sending a message or voicemail that are deferred later the callers can choose just to remind themselves to try again later. This can be a good alternative especially when the recipient and the caller are not mutually trusted contacts and do not share their status.

Finally, the "share your status" option allows the caller to share availability status with the recipient for either a defined time (10 minutes, 1 hour, etc.) or to solicit a handshake for status sharing, similar to the *friending* process in online social networks today. When the caller's status is available to the initial intended call recipient, they might make a better decision when to try to contact the initial caller again. Sharing status can also be enabled when the recipient blocks calls as seen in Figure 2.

Activity-Based Sharing In many driving situations, it would be useful to share location with other people without needing to make a call or to send a text message. However, people are concerned about their privacy in location-sharing applications [5, 14]. We decided to alleviate these concerns while enabling a simple way to share one's location. With activity-based sharing, the users can decide to share their location only for a certain period of time, related to an activity. Further, we designed the interface so that the actual location does not need to be shared at all, but only "estimated time to arrive [to your current or the scheduled location]". The fundamental idea behind activity-based sharing is that we enable sharing without requiring interaction during the sharing, and thus, people can solve their information needs without having to operate the phone then.

Activity-based sharing can be established by configuring it from e.g. the calendar interface of a mobile phone. Alternatively, the sharing can be configured from *after-call dialog*, which can be a natural place to configure after e.g. scheduling something on the phone. Configuration using the calendar interface is similar to the after call-dialog so we discuss only the latter due to space limitations. We note that some smartphones have already some limited after-call menus for helping users. For example, certain Android-based phones ask after a call from a number not in the contact list "Do you want to save this number to contacts" and present the options "1. Yes, add a new contact, 2. Yes, add to an existing contact 3. No, 4. Cancel".

In our design of the after-call dialog (see Figure 3) the user is briefly prompted with actions that include:

- Schedule Meeting (open calendar)
- Schedule Pickup
- Share Status (setup sharing preferences)

The meeting display prompts the user to choose the contact (e.g. Fred), to specify date, time, and location, which can be chosen from the map or from a predefined label. The calendar has also the option to setup sharing preferences, which can also be accessed directly from the after-call menu.

When choosing the sharing preferences option, the user is prompted to share status when driving/meeting or to share location when picking somebody up. Choosing yes to any of the options will result in an exchange with the intended contact and they will be informed of the decisions the first user make. Then, they will be prompted for sharing the same information for reciprocity, and for the purposes of calculating the estimated arrival time to a location.

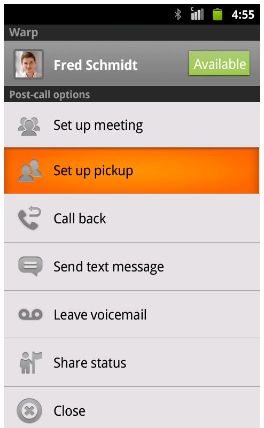

Figure 3: After-Call Dialog: Users are presented with an option to configure meetings, pickups and sharing preferences after finishing calls.

With the pickup option, the scheduler is prompted for the date and time of the pickup and for other contacts that the pickup should be shared with. It also includes the sharing preferences option. The effects of these decisions are illustrated in Section 2 above.

Time-Shifting The concept of time-shifting materializes our goal for not interrupting the mobile phone user while driving. The simple ideas are: 1) some things can be done *before* you start to drive and 2) some things can be done *after* you stop driving. Time-shifting is established with the combination of other techniques already discussed above. However, time-shifting is not triggered if there is an emergency, instead the call would interrupt the driver.

Example of the first type of time-shifting is scheduling and configuring meetings and pickups. With the interaction design discussed in the activity-sharing above, we can time-shift notifying desired people about locations while driving. The second type of time-shifting is to defer communication; e.g. the users are alerted and shown text messages after they have stopped driving.

Default Configurations In the proposed approach, we enable sharing contexts, which can be considered sensitive. Some of the described interactions enable very fine-grained and time-based granularity for sharing, however, we still need easy-to-configure defaults instead of complex groups and policies. Further, it should be configurable who the people that are allowed to call in an emergency are.

With mobile phones, natural groupings are "people not in your contact list (i.e. unknown people)", "people in your contact list", and "selected contacts". When users first use the application, they are presented with a simple question "who should be able to call you in an emergency even when you're driving" with the options 1) selected contacts, 2) everybody in contact list and 3) everybody (even unknown people). By choosing "selected contacts", the user is presented their contact list and has the option to check contacts that will be included to the "allowed to call in an emergency" list. We use this configuration also to bootstrap sharing information on status. The next step in configuring detaults asks "should these contacts be able to see your availability at all times?". We have also included these configuration options to the interface for adding new contacts.

4. RELATED WORK

We next discuss related work, which we have categorized into studies on distracted driving, interruptibility, and systems that help manage interruptibility or phone calls.

There is a wealth of research on adverse effects of handling a phone while driving (e.g. Salvucci [22]). A meta-analysis found that using a mobile phone while driving is distracting *even when the drivers are using hands-free interfaces* [4]. A recent simulator study by Brumby et al. [3] shows that even in an artificially simple case, using the mobile phone while driving can be dangerous: when experienced drivers were driving at 55 mph, and focusing on dialing a 10 digit number, the drivers even deviated over the lane boundaries. These studies emphasize our motivation for minimizing the need for operating the mobile phone while driving.

How interruptions affect people and how to predict human interruptibility have been studied extensively (a comprehensive survey is available e.g. in Fogarty et al. [6]). Ho and Intille [10] have studied the acceptability of interrupting a user while transitioning, for example, standing up after sitting, or starting to move after standing. The motivation for their work is similar to ours; the authors investigated when it would be a good time to interrupt the user, and possibly delaying delivering messages until that opportune moment. In general, with respect to interruptions by phone calls, research has shown that there is a mismatch between callers and callees [1]. Callees would like callers to consider different things that callers consider when they are making their calls.

Systems that provide alternative interactions BlindSight [15] allows the user to operate a mobile phone without watching it by providing auditory feedback. Negotiator [30] enables the caller and recipient to negotiate with a simple GUI a good time for the call in the future. Taming of the Ring [20] proposes pre-recording custom voice messages for different situations. With a press of a button, a suitable message would be played, e.g. "I'm in a meeting, leave a message and I'll get back to you soon, press # if this is urgent". Quiet Calls [17] goes further by allowing the user play pre-recorded messages while listening in on the call. The caller is greeted with a message saying that the recipient is listening but cannot answer, but recommends to go ahead, and the recipient can further acknowledge or inform the caller with different messages. In contrast to our approach, the problem with these approaches is that the callee is interrupted by the caller in all cases.

Context-aware systems Bayesphone [11] uses calendar, likelihood of attending a conference, and user-defined importance of the caller for real time analysis of whether the callee should be interrupted (by ringing the phone) or the call be directed to voicemail. Awarenex [26] displays location and calendar information in the phone contact list and Lilsys [2] later augments this approach by adding, speech, door, phone and motion sensors to the system. The idea behind the system is to present the caller with information about the probability that the callee is busy. The problem with these approaches, as reported by tests on Lilsys, is that the users were interrupted even when the system said they are busy: "I see you're busy, but I have a quick question".

Calls.calm [19] proposes displaying information of the context to known associates. The callee maintains information within three dimensions: role, location and social setting. For example, a colleague trying to establish a connection to a callee at work, might receive information "I'm here, but in a meeting", but an unknown caller might only receive information such as "I am at work but rather busy". The Calls.calm approach was only proposed but not implemented or further studied with users. DeDe [13] allows the text message sender to define the context when the text message is delivered. Users can define e.g. "deliver this message when the recipient arrives home". The contexts DeDe users could define were time, predefined location, phone call to or from a defined number, and if a distinct Bluetooth device is near.

The ContextPhone project [21, 18] studied providing contextual cues in the contact list of a smartphone. In their field trials [18], the authors found that users would not consider the cues at all when sending a text message. They did observe that users spent more time on initiating a call when the cues where present, which would indicate users at least noted the cues before placing a call. However, the increase in successful calls was only 12% for a specific study group. We observe that ContextPhone presented multiple and relatively complex cues to users. This led us to design a simple informative interface instead. Further, the results of ContextPhone motivated us to push the context information to users only when they are trying to place a call and burdening the callers with the context cues then.

We installed and tried applications available on the Android App Market and found that some applications could partially help to relieve the social pressure or desire to answer a text message while driving. For example, "smsreplier" application sends a response automatically to all text messages in the lines of "the person who you contacted is driving". However, we note that for a system to have real utility, it needs to automate not only answering text messages but all possible communication attempts that might distract the driver. Glympse [7] allows users to share their location with chosen set of contacts for a chosen time, but the problem with Glympse is the same as with our strawman approach: it needs to be manually enabled every time users start driving. Newport [8] enables location sharing during calls, however, we do not want people to be interacting with the phone during driving.

Finally, researchers have shown that presenting the caller with information about the driver's traffic status helps both the driver and the caller to interleave their discussion to accommodate traffic [24]. Unfortunately, the approach is not very practical for small mobile phone screens and would not help to solve the texting while driving problem. Also, providing a way for the caller to decide whether the call is urgent and should be passed through has not been implemented and studied before. Recently, researchers investigated how users would feel about an interface where urgency can be mediated by applying pressure on a mobile phone (more pressure, the more urgent the call) [9]. However, the study focused on the acceptability of the pressure-based user interface, not on the architecture and acceptability of having an "urgent call" option that would make it possible to interrupt callees even when they might be busy. In our approach, the default operation is that calls do not interrupt the user at all while driving, unless the calls have been explicitly chosen from the user interface to be "urgent".

5. DISCUSSION AND FURTHER WORK

In this section, we discuss some limitations, engineering and implementation issues with our design.

We first start by acknowledging that we do not solve all mobile information needs while driving. A further limitation is that we do not address the needs of those people who use their mobile phone to entertain themselves while driving by calling people or even playing mobile games. Our approach, however, addresses the social pressure and perceived need to answer a phone call or a text message as soon as they arrive: the caller or sender of a text message knows not to wait for a reply immediately, and the drivers do not notice anything that they would feel pressure to attend to. A possible problem with blocking calls from untrusted numbers is that it is possible that there is an emergency where an unknown party is trying to call. For example, perhaps the school tries to call parents that something happened to their children. In other words, it is an open problem that what is the appropriate amount of automation for this kind of context-aware communication system [23].

We have advocated location and context sharing as a useful tool to mitigate problems related to distracted driving. However, research has shown that people have concerns with sharing location [5] and context-aware telephony [14]. Our surveys and preliminary studies with paper prototypes indicate that the interaction design and activity-based sharing we propose would help to alleviate these concerns.

One major engineering problem that we have not solved yet is a robust way to detect whether a person in a vehicle is a driver or a passenger. We speculate that even the phone's accelerometer might be able to detect when we get into a passenger vehicle compared to a bus transport. With few exceptions, when entering a car, people sit down rather low before the vehicle starts moving. In a bus, the phone would first rise, then move, and then you would sit (and then the bus starts moving or at the same time). However, we might not be able to recognize at all if a person is sitting as a passenger e.g. in a taxi. We further note that robustly inferring these situations is difficult because some people keep their mobile phones in their pocket while others keep their phones in a bag. Some Android applications attempt to address this problem by assuming that if the sensors indicate the mobile is an a vehicle, the users need to be able to solve a puzzle to be able to operate their phones. However, there is not yet research available on the ramifications of these puzzles. For example, since some people are even playing mobile games while they are driving, would not these people be rather motivated to solve the puzzle to be able to operate their phones even though they should concentrate on driving?

Despite the reservations discussed above, for many users, detecting whether they are the driver or a passenger could be based on the car's Bluetooth ID. However, obvious objections to this approach are that not all cars have Bluetooth yet, and if the car is shared, many people in the family might be sharing the Bluetooth as well.

We have assumed in this paper that the caller is not driving. However, if the caller is driving, and tries to call somebody, our proposed approach could be detrimental for focusing on driving if the call recipient is using the system.

Finally, utilizing context-awareness has been proposed before for several kinds of interruptibility management scenarios other than driving, for example, for detecting when people are in a meeting and showing that they are busy. Even though our approach is motivated by scenarios related to driving, we believe our design could be applied to solve other kinds of interruptibility problems as well.

6. CONCLUSIONS

We have presented initial interaction designs for a mobile phone system that has the potential to nudge people not to operate their mobile phones while they are driving. We utilized context-awareness for burden-shifting from call recipients to callers. We also introduced two novel concepts: time-shifting and activity-based sharing that help address mobile information needs of drivers and the people who might call them. Activity-based sharing also provides an elegant way of sharing approximate location that can help to address privacy concerns related to location sharing. The core idea behind our approach is that drivers are not distracted by the mobile phone unless somebody they know and trust calls in an emergency. We believe our approach is a good first step for designing driving-friendly mobile phone systems.

Acknowledgments

We thank Christopher Edwards for his help with user interface mockups. We thank our shepherd Bill Schilit and our anonymous reviewers for their insightful comments. This work was supported by grants from Emil Aaltosen Säätiö, Tekniikan Edistämissäätiö, and Academy of Finland.

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