Important Context Changes for Talking and Text Messaging during Homeward Commutes

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ABSTRACT

This paper models the suitability of homeward commutes as a context for talking on a mobile telephone and text messaging. Analysis of these models identifies when and where large changes in suitability frequently arise. To bring commuters the greatest benefits, these are the changes upon which future applications of context-sensitivity and awareness need to focus.

Keywords

User model, context of use, mobile communication, awareness system, context-awareness, commuting.

INTRODUCTION

Context-sensitive Communication

There is current interest in the development of computer systems that support the initiation of communication, and negotiation about which service to use, and when to use it. For example, group awareness systems, and communication assistants display information about a device-owner's 'reachability' or 'interruptability' to people wanting to communicate with him or her [1][2][3]. There is also interest in adaptive communication systems. These systems apply an individual's communication 'policies' and preferences, so that the owner communicates the way he or she prefers (differently), in different circumstances. For example, a context-sensitive phone may be set so that it will not ring, if noise levels, or appointments in the device's calendar, suggest that its owner is in a meeting [4] [5].

The user group targeted by these systems is generally office workers, particularly those who want to communicate across time zones, those who communicate frequently (managers), and those with diverse activities (say, hospital doctors). The service targeted is often voice telephony, or other synchronous media, because coordinating two remote, but busy people requires time and effort that neither person has. Messaging, particularly urgent or broadcast messages, may also benefit, because judging the context correctly, ensures that important messages get through, and that unimportant messages are not disruptive. For example, an advertisement pushed to a user's PC, might be less disruptive, if it arrives between user activities, rather than during them. It is possible that technology developed for business in the first instance, may also be adopted by the general public, so some studies have concerned indicators of availability in the home[6].

To support development of these systems, one strand of user-centered work has observed office-based communication to identify the detectable features of context that most reliably indicate communication preferences – these are the features that will be informative to remote parties, and which need to be implemented by a system's model of the user. For example, one recent study used an experience sampling method to discover that the best predictors of an office manager's interruptability were, first, noise in the room, and second, his or her use of a computer [7]. Another strand of user-centered work has sought to identify the information about their own status that users are willing to share with various others (team mates, family, friends, managers etc.), and for what purposes [8][9]. Users, of course, may not permit systems to disseminate, or even utilize, status information that they consider 'private'.

The aim of context-sensitive and awareness systems is to reduce the 'barriers that routinely complicate communication', 'reduce cognitive load' and encourage 'socially acceptable phone use'[10][5]. It will be interesting to see whether users feel these benefits warrant the overhead of controlling sensitivity and stating their preferences, and any change in their relationships with other people[11].

Extension to Mobile Communication

A logical extension of these developments is to communication in 'mobile' contexts. Office workers often travel, and studies of communication in 'mobile' contexts have identified various 'obstacles to communication'. The obstacles identified in [12] are unsurprising – noise, bystanders and incidental eaves-dropping[13], patchy network coverage, the difficulty of reading a small screen whilst walking[14], and the needs of traveling conflicting with the needs of communication[15].

Various kinds of hardware have been developed to make it easier for users use the communication service they prefer in adverse transit situations, for example, headsets and car adapter kits for drivers, wearable devices for walkers, and portable keyboards for train passengers. However, such hardware may not be the only solution. After all, only some mobile phone owners have choosen to purchase additional hardware. Additional hardware can be expensive, can become separated from the phone, and is only compatible with some phones. Other users, it is suspected, would prefer to overcome 'barriers that complicate communication' with software. Also, some users, it is suspected, do not need to communicate 'anytime, anywhere, anyhow'. Rather, they would prefer to adapt their phone use to their mobile context – to be temporarily unavailable when the immediate surroundings are unsuitable, and to encourage phone use at times and places of their liking. Better 'ordinary' mobile phone software is also desirable from a road safety point of view. For various reasons, it has proven difficult to regulate the unsafe use of mobile telephones, and so road accidents continue to be result from individuals driving whilst using their mobile phone. However, it may be easier to regulate against the distribution of software that is 'unsafe', because it is unaware of its context of use.

Any development of software that enables users to reschedule or reform communication around 'mobile' contexts, however, needs to prioritize features that are likely to bring users the greatest benefits. The evidence for potential user benefits (to the extent that it has been gathered), is not strong. For example, a recent study found that user experience of communication about a rendezvous was worse when communication occurred en route to the rendezvous point, compared to when it occurred prior to departure[12]. However, the reduction in user experience was only about one third of a rating point on a five-point scale, and the overall level of ratings remained very positive (around 4/5, or 1.3/5 as appropriate). Other surveys *do* report 'barriers to communication', but only at modest levels (see Table 1)[16][1]. It is difficult to imagine how 'barriers' of this kind could warrant the implementation of every adaptation to every context, or similarly, awareness of every aspect of every context. So, which changes in context offer the greatest opportunity to benefit users? What is the traveller's equivalent to the office worker's 'having a meeting'?

[1] Note this evidence is based on students, not high-frequency business users.

Statement	Agree
1. Because of the context of use, my experience of phone use was impaired	22%
2. I attempted to find a suitable personal context for using the phone	39%
3. I prefer not to use the phone in this context, but on this occasion I felt I had to.	47%
4. Because of my personal context, use of the phone was cut short/completed later	20%
5. I delayed my journey to use the phone	14%

Table 1. Barriers that complicate mobile phone use: frequency

Identifying Large Fluctuations in Mobile User Performance

One approach to answering this question is to identify large fluctuations in the performance of mobile users as they travel and their immediate surroundings change. 'Dips' in user performance suggest situations in which the effects of an adverse context can be made good by adaptation or awareness. Of course, identifying large fluctuations in user performance (quality of outcomes achieved for costs incurred) provides limited support for detailed design, because it does not reveal much about user behaviour. But detailed design is not the problem - the problem is identifying which situations it is important to design *for*.

Modeling the performance of mobile users is of general interest, because various kinds of context-sensitive applications are currently under-development – from navigation aids that use mode of transport, speed of movement, and indoor/outdoor status to adapt the positioning mechanism, way-finding algorithm and map display[17], to care-worker applications that use time, location and connectivity, to enable/disable command buttons, download information in advance of use, and show/hide user interface components[18]. Awareness applications could also support various kinds of mobile group work, such as problem-solving, or planning. The approach is also of general interest, because continuous models of user performance over *time* have long been used to support 'stationary' systems design (cf studies of vigilance amongst radar operators, or effects of shift patterns on worker productivity). However, the use of continuous models of user performance *over time and space* (time geographic models) is novel, so it will be interesting to see what these models can contribute to 'mobile' systems development.

AIM

The aim of this paper is to develop and apply models of user communication performance during homeward commutes. To this end, the paper models the suitability of each segment of university students' homeward commutes as a context in which to talk on a mobile telephone or to use text messaging. The models are developed using a combination of knowledge elicitation and diary keeping. The models are then analysed to identify travel situations that are associated with large changes in suitability.

Homeward commutes were selected for study, because it is important to design for frequently made journeys. Studying the commute also enables the use of knowledge elicitation techniques (see next Section), because it is so routine that users are very knowledgeable about it, and because it lasts long enough for participants to regularly use their phones during it.

EMPIRICAL STUDY

The empirical study utilised a combination of knowledge elicitation and diary keeping activities that used tables and maps. Elicitation was used to develop models of commutes with the full, and direct participation of users. Diary keeping obtained reports of actual phone use in context, and was used to discover the frequency of actual, rare events, in a safe way, and without distorting the topic being studied[2]. The combination of elicitation and diary keeping techniques enabled an informal check of the consistency of the data for each participant – a participant's 'knowledge' of their habits and the context's general suitability for phone use, should be consistent with diary entries about occasions on which they actually used their phone. The diary also gave insights into participants' behaviour that elaborated and explained the models and analysis.

Method

The study method comprised a three step process. In step 1, participants described their most regular journey from their place of work to their home address as a number of stages or 'segments'. In step 2, they kept a diary of their actual phone use during this homeward commute, and in step 3, they described the suitability of each segment of this journey. Diary keeping (step

[2] Ways of using wireless networks and devices to capture 'mobile' field data, and ways of improving traditional diary techniques, are currently being investigated and developed ([19][20][21]), but not soon enough for this study, which began in December 2003. Traditional experience gathering procedures will expose participants to small, but knowable risks in 'mobile contexts - being distracted whilst driving, and drawing attention to oneself in potentially 'unsafe' neighborhoods. This research did not absolutely need to expose participants to these risks.

2) was inserted before the final step of elicitation (step 3), to focus the participant's reflections on an explicit set of recent experiences.

Participants

The participants in this study were 10 male and 10 female students attending the School of Computing and Information Systems, Kingston University on a full-time basis. Participants were aged between 20 and 27, and had a mean age of 22 years and 4 months. In terms of ethnic background, 40% of participants were Asian, 45% were European and 15% were 'other'. An equal proportion of frequent and infrequent users of mobile phones participated (50% made at least 10 personal voice calls from their mobile phone per week, and 50% sent at least 10 text messages per week). 9 participants commuted by public transport (bus and/or train) and 11 drove a car. On average, participants' commutes lasted 52 mins 9 secs, and covered 12.5km – about average for Londoners. The duration of, and distance covered by, a commute was similar for those taking public transport, and those driving. All participants used an 'ordinary', one-piece handset. Drivers who used a hands free kit, whether in the form of a headset (microphone and earphones), or and adapter for in-car speakers and microphone, and whether connected by cables or BlueTooth, were not included in the study.

This sample of participants is balanced in terms of many relevant characteristics - modes of travel, duration and distance of commute, frequency of use and gender. However, it is not representative of mobile phone users, because of participants' age (young adults), occupation (student) and ethnic background (for the United Kingdom, Asians are over-represented). Also, in this sample, females tended to commute by bus and/or train, but males tended to commute by car[3]. This appears to reflect real life for students at Kingston University. The limitations of this sample of participants need to be borne in mind when attempting to generalize the results.

Procedure

In step 1, elicitation of commute, each participant described their homeward commute as a table and a map (see Table 2 and Figure 1). Attempts to complete the table often revealed ambiguities or incorrectness in the map, or vice versa, which prompted further questioning. Each row in the

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[3] Of the 10 males, 3 commuted by bus and/or train, and 7 drove a car. Of the 10 females, 6 commuted by bus and/or train and 4 drove.

table described one step or ‘segment’ of their most habitual route from the university campus to their home. The segments identified were sufficient to clearly distinguish the route taken from alternative possible routes. The map showed the route taken, and highlighted key nodes. The table and map were then copied for reuse during steps 2 and 3.

In step 2, diary keeping, each time the participant used their phone during their homeward commute, the participant described: (i) their use of the phone (the service used, when and where the service was used, who initiated use, the duration of usage, and quality of user experience); and (ii) the personal context of use, in terms of environmental, cognitive, biomechanical, workspace, and social factors. The time and place of phone use was stated by editing the table and map produced in step 1. Participants were also invited to update the description of the most habitual route produced in step 1, for example, with more accurate timings, or additional segments. Participants kept a diary until they had reported five phone uses, or for three weeks, whichever was the sooner.

In step 3, elicitation of suitability, the participant rated each segment of their commute in terms of its suitability on a scale from 1 (very unsuitable) to 5 (very suitable) for various kinds of phone use - making telephone calls, taking telephone calls, writing text messages (SMS) and reading text messages. Participants were then invited to segment their route differently to step 1, but few did so. Participants were also invited to identify ‘blackspots’ and ‘brightspots’ along their commute – smaller, and briefer changes in suitability, for example, at traffic lights, or when boarding/alighting from a train. However, no such ‘spots’ were volunteered - those that did so, only repeated segments already identified in step 1.

Legal Context

Data was collected in November – December, 2003 (12 participants), and November – December 2004 (8 participants). On December 1st, 2003, use of handheld phones whilst driving was made illegal in UK, with on the spot fines of around £30. When the new law was introduced, the majority of drivers were either unaware of the new law, confused about the nature of the ban (it prohibits holding a mobile phone whilst driving), or uncertain how strictly it would be enforced. A year later, more drivers understood the ban, but many ignored it to some extent, as is still the case today. The law is enforced with a degree of tolerance – other road users may yell at a driver on the phone, but generally speaking, law enforcers have more important things to do unless it is claimed a driver was on the phone when an accident occurred, in which case the driver's phone records may be checked.

Modeling and Analysis

The raw data obtained from participants, together with road and rail data for the area covered by the commutes, was loaded into ESRI's Arc View 3.2, a popular Geographic Information System. Some incompleteness and/or incoherence in paper models were identified at this stage. Typically, abbreviations or incorrect spellings had been included in the paper models - they appeared to reference places that were not on a plausible route. When errors in the table were found, such as a missing segment for waiting at the station to catch a train, the participant was e-mailed for clarification.

The models were analyzed by reading raw data into a java program, which then made the following calculations:

i) the mean suitability of the commute;

ii) the suitability of each kind of transit 'locale' i.e. segments, in which the participant was walking, waiting, on a bus, a train, or driving;

iii) the direction and magnitude of the changes in suitability for each transition between locales, and so the overall fluctuation ("changeability") of the commute (how 'dynamic' was the context of use);

iv) the nature and frequency of large changes (2 or more rating points) between adjacent segments.

ID	FromNode	From Time	ToNode	To Time	Activities	Situation	Suitability for Phone Use			
							Make Call	Take Call	Write SMS	Read SMS
1	room SB115	17:00	Fassett Rd car park	17:03	Walk check messages and missed calls	Quiet, empty	3	2	2	3
2	Fassett Rd car park	17:03	Fairfield North.	17:08	biking	quiet streets	3	2	2	3
3	Fairfield North	17:08	Elm Rd.	17:11	walk with bike	busy road, narrow path	1	1	1	2
4	Elm Rd	17:11	Turners Hill	17:25	biking	Quiet roads, dark in park	3	2	2	3

5	Turners Hill	17:25	Nursery	17:35	Biking	Busier roads, fast downhill	2	1	2	2
6	Nursery	17:35	Nursery	17:40	Collecting child	Noisy	3	3	2	4
7	Nursery	17:40	Home	17:50	Walking with child	some road noise	3	3	2	4

Expectations

At the outset of the study, driving was expected to be the least suitable transit locale for using a phone – it is mentally demanding, unsafe, and illegal. It was also expected that suitability would fluctuate during the commute. However, the literature identified so many problematic features of context (see [12]) that the relative suitability of different locales was difficult to predict.

It was also hoped that at least some large changes in suitability would be plausibly related to position. The author has a long-standing interest in context-aware applications that utilise position data [21], and this study might suggest opportunities to use position data to enhance communication. For example, if a few segments of the drive home are highly unsuitable for telephone calls, but the majority are acceptable, then cellID could be used to delay calls that are received in unsuitable segments of a commute. If a call arrives at a 'bad time', then the caller is told that the intended recipient is driving, and put on hold. As soon as the driver is in a suitable segment, the caller is 'put through'.

RESULTS

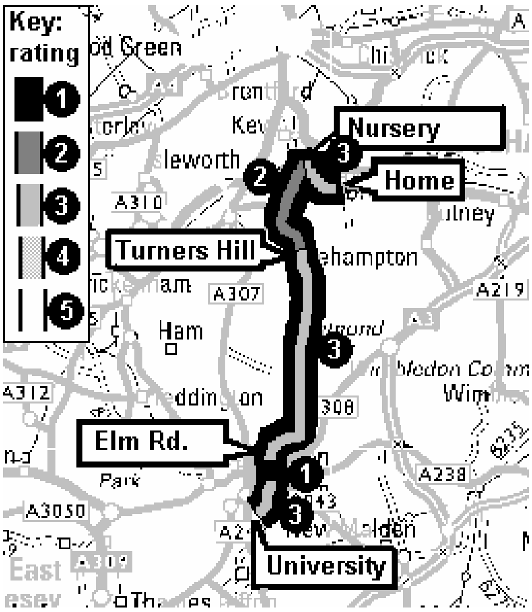
Models for Individual Participants

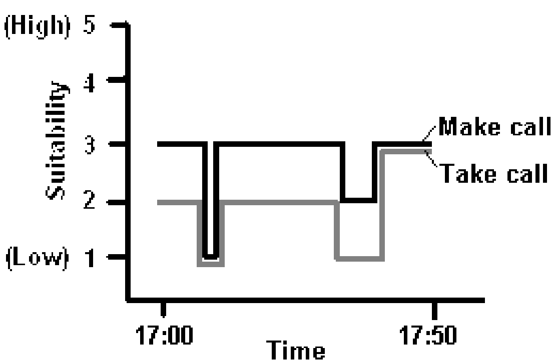
Table 2, and Figures 1 and 2, represent the suitability for using a mobile phone of a homeward commute by bicycle (the pilot subject). The model is represented as a table, a map and two graphs.

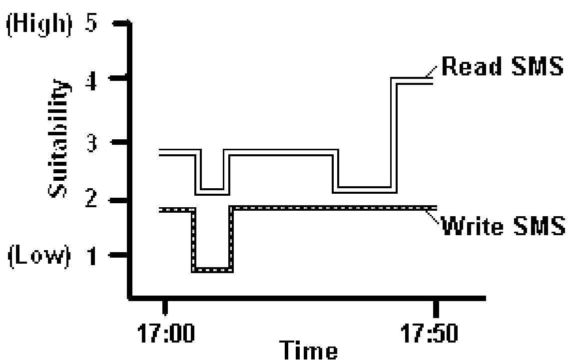
Figure 1: Suitability of a homeward commute as a map (Making calls)

Table 2: Example model of suitability of a homeward commute (all services)

Figure 2. Model of suitability of a homeward commute as graphs (telephony and text messaging)







The model shows that, for the pilot subject, the segment in which he walks along suburban streets with a bicycle and minding a child (segment 7) is about as suitable a segment for making a phone call as the one in which he cycles along a quiet, but unlit road (segment 2). Both segments are fairly mediocre, because, to make a call, the participant has to pull over to a quiet point on the pavement, get the phone out of his bag and keep his eye on the immediate situation. Both of these segments are slightly more suitable than segment 5 (riding fast downhill along a fairly busy road), because pulling over to the side is more disruptive, and there is more background noise.

Analysis of Models

Suitability of Commutes

The mean suitability of a homeward commute for different kinds of phone use is shown in Table 3. Overall, commutes by public transport are more suitable for using the phone than commutes by car (two-tailed T-test, sig. = 0.024). The type of phone use *per se* did not effect suitability ratings.

Table 3: Mode of transport x phone use: mean suitability

	Make Call	**Take Call**	**Write Text**	**Read Text**	**All Phone Uses**
Car	1.87	2.03	2.01	1.98	1.97
Bus/ Train	2.52	2.51	2.71	3.22	2.74
All Modes	2.16	2.25	2.32	2.54	2.32

Suitability of Transit Locales

The mean suitability for using the phone during particular types of segment, or transit locale, is shown in Table 3. The participant's transit activity during a segment effects the context's suitability for all kinds of phone use (chi^2, make call sig. = 0.050, take call sig. = 0.038, write text sig. < 0.001, read text sig. = 0.001). Where relevant, the suitability of each type of locale is not different for commutes by car and public transport.

Work[4] /Home	Walk	Wait	Bus	Train	Drive
3.25	2.76	2.56	2.44	2.40	1.87

Table 4: Type of transit locale: mean suitability

The ratings for type of transit locale probably explain the lower suitability of commutes by car (see Table 3) – although these journeys begin and end with a walk [5], users are driving most of the time, and driving has the lowest rating.

Fluctuation in Suitability

The fluctuation in suitability during a commute is quantified, here, as ‘sinuosity’ – the ‘curviness’ of the profile as plotted in Figure 2. Sinuosity is the actual length of the profile (the ‘curve’) as a proportion of its shortest possible length (a horizontal line, indicating a constant value). The more frequent and extreme the changes in suitability, the higher the value for sinuosity[6]. The minimum value of sinuosity is 1. Since the commutes studied here comprised an average of 7 segments, and suitability was rated on a 5 point scale, the maximum possible value of sinuosity is 4.4 (the result of ((6*4)+7)/7)[7].

The commutes elicited in this study have a mean sinuosity of 1.84 - somewhat low. This figure is not significantly different for particular modes of transport, or types of phone use.

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[4] Segments for ‘work’ and ‘home’ were not included in previous calculations of suitability of commute, because their duration is not limited. However, they are a useful comparison in the table.

[5] Empty spaces and free parking is difficult to find throughout London, particularly around campus. Many participants have a 5-10minute walk from campus to their car, and then another walk from their car to their home.

[6] Sinuosity is used here, because the frequency and magnitude of change is important. Measures such as standard deviation are not appropriate, because a commute with a single large step (not very fluctuating) may have the same standard deviation (average difference from the average) as a frequently oscillating profile (very fluctuating).

[7] Sinuosity may be calculated in various ways. This paper is concerned with the value for sinuosity relative to the extremes of the scale, rather than the absolute value.

Large Changes in Suitability

Overall modes of transport, only 17% of transitions are associated with large changes in suitability (at least 2 rating points). For commutes by car, however, the proportion is 24% (about twice per commute) and, for commutes by public transport, 8% (less than once per commute).

An inspection[8] of the large changes in suitability reported, suggests that they are particularly associated with some types of transition between transit activity (see Table 4). During commutes by car, large falls occur when a driver reaches his or her car (walk-drive), large increases occur when a driver stops driving (drive-walk), and large increases and falls also occur during a car journey (drive-drive), particularly for messaging. During commutes by public transport, large changes sometimes arise when those taking public transport board their bus and/or train (wait-bus/train). Large changes are also associated with other transitions in commutes by public transport, but no clear pattern emerges.

	Make Call	**Take Call**	**Write Text**	**Read Text**
Car				
Walk-Drive	7	6	5	4
Drive-Drive	3	3	7	8
Drive-Walk	7	7	7	6
Total	***17***	***16***	***19***	***18***
Bus/ Train				
Walk-Wait	0	0	0	0
Wait-Bus/Train	3	3	4	3
Bus/Train-Wait	0	0	0	0
Bus-Bus/Train-Train	2	0	0	2
Bus/Train-Walk	2	0	0	3
Total	*7*	*3*	*4*	*8*

Table 5: Transition x phone use: frequency large changes

[8] There are too few large changes to support statistical analysis. (Recall the mean values for sinuosity were somewhat low)

DISCUSSION

What Changes in Context are Most Important?

Commutes by Car

Large changes were associated with walk-drive, because driving is the least suitable transit locale, and walking is the most suitable (see Table 4). Diaries suggested that imminent driving combined with the study environment at university to 'compress' phone use into the walk to the car. Use of mobile phones is banned in many areas of the university (lecture theatres, teaching laboratories, libraries etc), so many drivers habitually check their phones for missed calls and messages, reply to any they have received, and/or make other calls, as they walk to their car. Some participants were even willing to delay travel to compress phone use into this relatively suitable 'pre-amble' to their journey.

- *Participant 6 Use 4*: She received a call as she walked along quiet streets to where her car was parked. She was still talking as she reached the car, and so just sat in the car for a few minutes until the call was over. She did not want to talk and drive at the same time.
- *Participant 11 Use 1*: He had just pulled out from his space in the car park when he received a call from a friend (a social call about university work). The car park was empty, so he stopped the car, and took the call.

Large changes were associated with drive-walk, because again the most and least suitable transit locales are juxtaposed, and drivers are emerging from a period of reduced availability. Diaries suggested many drivers habitually turned their phones off, or "tried not to use" their phone whilst driving, and so checked their phone and responded to communications as they walked home.

Large changes for text messaging were associated with drive-drive, because near stationary queues of traffic reliably occurred for short periods of the commute, often at the approach to traffic lights or junctions. Suitability for messaging rose when the driver joined almost stationary queue of traffic, and then fell as the congestion was left behind. Some drivers liked to take advantage of these temporary 'brightspots' in their journey, because they thought it was safe to use the phone, phone use was a welcome diversion, and they sometimes felt obliged to investigate communications, because they might be urgent (they rarely were). A brightspot is more suitable for text messaging than telephone calls, because messaging is easier to perform in a short period of time, more interruptable (and so good for interleaving with driving), and easier to complete once started.

- *Participant 2 Use 2*: His habit was to not use the phone at all whilst driving home. If necessary, he would wait until he reached a reliable jam at some traffic lights about 15 minutes from home, and use the phone there. One evening he was getting bored, so when he reached the jam, he sent a quick text message to his friends to find out their plans for the evening.

Commutes by Public Transport

No clear pattern emerged to large falls during commutes by public transport. The locales of 'waiting' and 'on a bus/train' are more similar than 'walking' and 'driving' (see Table 4). Waiting is a little worse than walking – bus stops can be crowded, and adjacent to noisy, main roads, whilst the walk out of university or from the stop to home, is often along quieter, side-streets. The bus or train is better than driving – bus passengers have no driving task to perform, or laws to observe.

Diaries suggested that individual differences between participants and transit locales are more noticeable when commuting by public transport. Although some busses, and bus stops are noisy and crowded, others are not, and participants varied in their sensitivity to potentially adverse context factors. For example, some taking public transport habitually used their phone once they had arrived at their bus stop or station ('waiting'). For these participants, the bus stop was suitable, because they were no longer out of breathe, and were able to access their phone and organize their personal space. Their earlier walk was along busy roads and pavements, and their subsequent bus/train ride was noisy and crowded. Other participants, in contrast, used their phone once on their bus or train – for them, the bus/train ride was a reliably quiet and comfortable segment of their journey, and they did not mind bystanders overhearing. For them, the bus top was worse.

Focusing Design on Important Changes

The goal of this study was to identify important changes in context. The above analysis achieved this goal. The three most important changes are:

(i) Walk-drive (for all kinds of phone use);

(ii) Drive-walk (for all kinds of phone use); and

(iii) Drive-drive (for text messaging).

At the outset of the study, it was envisaged that a few, highly unsuitable segments of the drive home could be avoided, by putting callers on hold until the driver was in a more suitable segment. To the extent that 'driving' is identified as the traveller's equivalent to the office worker's 'being in a meeting', it was not wholly misplaced. However, this idea does not respond to the three priorities above. Indeed, the implicit model of commuting – a few highly unsuitable segments, interrupting a majority of suitable driving segments - is inaccurate.

To illustrate the value of modelling the performance of mobile users, this section suggests some design options for the three important changes transitions identified above. Following the interests stated earlier, the options concern software that enables users to re-schedule or re-form communication in the face of a changing 'mobile' contexts, and focus upon possible uses of position data.

Options for placing and accepting communications include:

- As a kind of enhanced Caller-ID, provide drivers with more information about in-coming calls or messages, without requiring the driver to touch, or look at the device. Different ring tones could distinguish urgent and non-urgent telephone calls, and indicate the individual, or 'user type' who wants to communicate.
- As a kind of enhanced ring tone, when a remote party places a telephone call to a driver, the caller is told that the phone owner is driving, and kept 'on hold' for longer before being cut off from an unanswered phone. This gives a driver more time to stop the car before answering.

Options for location-enhanced messaging include:

- Make it possible for a car commuter to prepare messages in advance (e.g. as they walk to the car), and then send the message automatically whilst they are driving. For example, notifications that the commuter has reached a certain point in the journey, could be triggered by time or position. Relatively coarse position data based upon cellID may be sufficient for this. A relevant prototype was recently trialled [22].
- Make it possible to trigger delivery of a message to a driver, during the initial walk to the car, or as the commuter walks from the car to home. For example, reminders to buy something on the way home, or that evening, could be triggered by logging off from office workstations, or by automatically signing out of the building. CellID is not sufficiently accurate position data for this, at least in the Kingston area, because communications must begin soon after the start of the walk, to complete it before the walk has ended. O-OTD, with accuracy of may be sufficient.
- Make it possible to delay delivery of non-urgent messages until the commuter has reached a 'brightspot'. For example, push advertising could be delayed until a model of that individual's travel patterns, and positioning mechanisms, suggests the driver is in a traffic jam. O-OTD would be sufficient to infer that a device was more or less stationary. Alternatively, the commuter could define 'brightspots' of their own, perhaps using maps similar to Figure 2.

Options for awareness include:

- Subject to prior authorization, remote callers may request a map of the car commuter's driving habits, phone use and current position. A prospective caller may then be able to figure out when best to phone. For this, O-OTD would be sufficient.

Methodological Issues

With hindsight, it would have been interesting for diaries to specifically ask participants why they did *not* use a headset or car kit. By so doing, evidence for important design assumptions would have been obtained.

It would also have been valuable to complement the elicitation techniques used in this study with some kind of direct observation. Direct observation would be able to capture briefer, though reliable variations in performance associated with, for example, difficult driving situations, boarding/alighting from buses, walking across dual carriageways etc. Direct observation would also be able to validate the models elicited, for example, by correlating the suitability rating elicited for a segment, with the actual quality of phone uses reported within that segment.

Perhaps the greatest limitation of this study, however, is that the 'mobile' context of use studied (the homeward commute) did not vary as much as statements about "the dynamic nature of 'mobile' contexts" might suggest (see Table 3). With the benefit of hindsight, communication during homeward commutes may not have been the most suitable 'mobile' context for trialling our approach. Perhaps other kinds of work on the move, such as salesmen visiting customers, may have resulted in more sinuous models, and so greater opportunities for context-sensitivity and awareness.

CONCLUSIONS

This paper has reported the use of knowledge elicitation and diary keeping techniques to study university students' use of mobile phones during homeward commutes. It has modeled a 'mobile' context's fluctuating suitability for interaction, and analysed these models to identify the large changes in suitability, that are important targets for design. It is hoped that future developments can respond to user priorities.

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