On The Impact of Real-Time Feedback on Users' Behaviour in Mobile Location-Sharing Applications

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ABSTRACT
Effective privacy management requires that mobile systems' users be able to make informed privacy decisions as their experience and knowledge of a system progresses. Prior work has shown that making such privacy decisions is a difficult task for users because systems do not provide support for *awareness*, *visibility* and *accountability* when sharing privacy-sensitive information. This paper reports results of our investigation into the efficacy of real-time feedback as a mechanism for incorporating these features of *social translucence* in location-sharing applications, in order to help users make better privacy decisions. We explored the role of real-time feedback in the context of Buddy Tracker, a mobile location-sharing application. Our work focuses on ways in which real-time feedback affects people's behaviour in order to identify the main criteria for acceptance of this technology. Based on the data from a three week field trial of Buddy Tracker, a focus group session, and interviews, we found that when using a system that provided real-time feedback, people were more accountable for their actions and reduced the number of unreasonable location requests. We have used the results of our study to propose high-level design criteria for incorporating real-time feedback into information sharing applications in a manner that ensures social acceptance of the technology.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: Evaluation/methodology, Graphical user interfaces (GUI), User-centered design. H.3.4 [**Systems and Software**]: Current awareness systems, user profiles and alert services.

General Terms
Design, Experimentation, Human Factors.

Keywords
Feedback, mobile computing, location based services, privacy management, social translucence.

1. INTRODUCTION
Many studies have shown that users are not very good at understanding the future value of keeping personal information private [1,2]. Some solutions involving location privacy policies have been suggested (e.g., [3]). However, prior research shows that end-users have difficulties in expressing and setting their privacy preferences, and their privacy policies change only marginally, unless they are given privacy tools that help them understand future implications of their privacy-related choices [2,4]. Moreover, setting privacy rules is a time-consuming process, which many people are unwilling to do until their privacy is violated. We see this as a strong motivation to design tools that help users to make informed privacy decisions as their experience and knowledge of a system progress. In the spirit of Palen and Dourish [5], we propose to build privacy-sensitive systems supporting the continual and selective disclosure of personal information by providing *real-time feedback* as the method of informing users about how their location information is being used. In our work we define feedback to be the notification of information disclosure, where the notification specifies what information about the person is disclosed when and to whom. This definition is drawn from the work of Bellotti and Sellen who considered feedback as "*informing people when and what information about them is being captured and to whom the information is being made available*" [6]. While such feedback-oriented support for privacy management has been studied on conventional (large screen) computers [7,8], innovations are needed for mobile devices. Therefore we decided to explore the role of real-time feedback in managing privacy in mobile location-sharing applications.

In this paper we present a location-sharing service grounded on the concept of *socially translucent systems* proposed by Erickson and Kellogg [9]. Translucency is achieved by real-time feedback providing *awareness* and *visibility* in the form of ad-hoc warnings displayed on, or generated by, the mobile device. Obviously, information about who has accessed one's location information might have a positive effect, i.e. improving the comfort of using location-sharing technologies, openness or fewer privacy concerns [7]. However, our preliminary results suggest that this is not always the case, especially from the perspective of data requesters. Our field trial with the real-time feedback feature showed that people were more *accountable* for their actions if they knew that the data owner would be notified of their request. This supports the third characteristic of *socially translucent systems*: *accountability*. Providing feedback to those whose location is being checked resulted in better awareness and understanding of the location requests made by others. This resulted in location requests being made only when the requester has good reason to do so.

We explore the role of real-time feedback in privacy management in the context of Buddy Tracker, a mobile location-sharing service we developed, by asking the following questions:

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1. *What is the impact of real-time feedback on users' behaviour?* We investigated users' reactions to this technology and how it affects users' behaviour.
2. *What are end-users' criteria for socially accepted real-time feedback system*? We were interested in how to build a context-aware real-time feedback manager system for supporting awareness that meets users' needs.

The next section of the paper discusses related work relevant to the concept of feedback (Section 2), followed by our classification of feedback mechanisms for mobile applications (Section 3). Next, we present the technical details of the Buddy Tracker system that we built for the purpose of our research (Section 4). This is followed by the presentation of our findings from a focus group session, interviews, and the field trial of Buddy Tracker with real-time feedback feature. Section 6 describes some high-level design guidelines for incorporating real-time feedback into systems, which we have developed on the basis of our experimental results. Finally, Section 7 summarizes our results and describes the most pressing research issues related to real-time feedback, which form the basis of our future work.

2. RELATED WORK

Feedback can be viewed from different perspectives, such as supporting machine learning [10], maintaining privacy policies or supporting collaborative work [6,11]. In this paper, we consider feedback from the perspective of sensory representation for personal privacy support.

Previous work on feedback has produced a wide range of results for different contexts and activities. Bellotti and Sellen [6] studied the use of feedback to show users of the RAVE environment that they were being recorded. They found that feedback in the form of an LED light is a good communication tool but that displaying the full information about people watching is too intrusive.

To provide a "just-in-time" descriptions of who is requesting information and why, Hong proposed the concept of *access notifications* represented as a dialog window with additional controls for accepting, denying or ignoring request. *Access notifications* support plausible deniability and also act as a privacy management tool [12]. Sellen et al. [13] proposed a novel design for a situated device, *The Whereabouts Clock*, presenting real-time information of "what the group is up to" based on a fictional device described in J.K. Rowling's *Harry Potter* books.

Another attempt to provide feedback about location requests was presented by Sadeh et al. [4]. They proposed a design for both real-time and aggregated feedback mechanisms. The first was a bubble notification (as used in the Windows Operating Systems); and the second was a location request history list, showing who had access to what information and when. The bubble was found as a minimally disruptive method for supporting awareness, which is one of the goals of our research. A similar interface was presented by Lederer et al. [8] who also designed an interface for a disclosure log to help people understand their privacy policies. A shortcoming of the latter design is that it does not provide a mechanism for making suggestions and refining privacy preferences ad-hoc. Tsai et al. [7] proposed a similar interface for a disclosure log. They found that feedback is a very important design feature supporting user's acceptance of location-sharing technologies and improving the comfort of sharing location. They also highlighted the correlation between the feedback availability and openness.

Raento and Oulasvirta [14] discuss the concept of historical feedback in the form of disclosure logs for location information on mobile devices. Their interface provides both coarse-grained location request information, and fine-grained view available on demand.

The work described so far has focused strongly on visual feedback, which is not appropriate in all contexts. Previous work in using feedback for privacy support also does not address the issue of contextual real-time feedback, and using alternative sensory representations (not only visual) for supporting privacy. For example, vibro-tactile and auditory feedback has been used successfully in other domains such as mobile search [15], navigation [16,17] or supporting visually impaired people in reading graphs activities [18]. We are interested in supporting *visibility*, *awareness* and *accountability* by extending the traditional ways of communication through new interactions.

3. FEEDBACK CLASSIFICATION

Our work seeks to find appropriate location privacy feedback mechanisms for a variety of contexts. We have designed a model for studying the role of feedback in location privacy management by classifying feedback along three dimensions: sensory, interaction and time. Consider the following example context scenarios:

SCENARIO 1: *Alice and Bob are users of the Buddy Tracker application. Bob checks on Alice's location when she is giving a presentation in a meeting. A blue LED light on her phone started flashing when she was presenting her slides (the blue light indicates that someone is checking one's location). She glanced her phone and after the meeting Alice checked who was checking her location.*

SCENARIO 2: *Alice is playing the favorite game on her mobile phone. While she was playing, a warning pop-up appeared saying that 'Bob just checked her location'. The game paused. She felt very annoyed as she lost her place in the game due to the alert.*

These sample scenarios show a positive and negative example of how we can incorporate the real-time feedback within the spectrum of mobile privacy interaction. They also show how feedback can be delivered, describe the time when information is delivered, and also what triggers delivery of real-time notification. In order to support our studies on feedback in privacy management we have distinguished the following three feedback dimensions.

3.1 Sensory Dimension

The sensory dimension (S) relates to the feedback representation, describing how information will be communicated to users. We have identified three subgroups of the sensory dimension:

- **Auditory feedback S(A)** describes any audio interaction between the system and the user, which has been recognized as an intuitive and unobtrusive medium for communication [11]. It can be as simple as a distinct musical tone playing when the event occurs or it can incorporate fully descriptive natural language feedback.

- **Visual feedback S(V)** relates to any visual element or feature on a mobile device that supports interaction including GUI elements used in ad-hoc communication. It can be used to represent the current state of the system, and also to display aggregated information based on historical data, i.e. icons, warnings, dialog boxes, privacy critics [19], disclosure logs [4,8,7], or map visualizations. Visual feedback can be also represented via hardware features, which relates to any visual feature of mobile device design that can be managed programmatically and used for communication (e.g. the LED light in HTC G1 Android phone[1]).
- **Tactile feedback S(T)** describes the vibro-tactile interaction between the system and the user such as the phone vibrating when an event occurs.

3.2 Interaction Dimension

The interaction dimension (I) describes how sensory representation of feedback is triggered. Feedback can be released automatically or on demand.

- **Automatic feedback I(A)** is released without user's intervention, every time the event occurs. Example: as soon as Bob checks the current position of Alice her phone immediately vibrates and plays a sound.
- **On demand feedback I(OD)** refers to a manual request made by the user, e.g. Bob shakes his phone to display a list of friends that accessed his location within last hour, or he chooses a menu option to list everyone .

3.3 Time Dimension

The time dimension (T) describes the temporal freshness of the information communicated via feedback mechanisms characterized by the sensory dimension. It can be divided into two categories:

- **Real-Time Feedback T(RT)** is designed to support users' awareness and visibility by providing timely information.
- **Aggregated feedback T(A)** relates to any aggregated information based on historical data from disclosure logs.

3.4 Mobile Interface Elements for Feedback

Below we describe examples of mobile interface elements that could be used to provide feedback. Each interface element supports different sensory representations of real-time feedback, including real-time and aggregated information delivery through automatic interaction.

- **Dialog box** – pop-up like window provides controls for specifying privacy choices. When the dialog box is open the user can not perform any action until it is closed (Figure 1a).
- **Toast** – small pop-up displaying few lines of text in the bottom of the screen which disappears automatically after 2 seconds. It does not prevent user from using the phone.
- **Notification bar** – notification on the status bar (top part of the screen), adds an icon indicating type of event, with an optional ticker-text message. It does not prevent user from using the phone (Figure 1b).

Figure 1. Selected visual representations of real-time feedback interfaces.

- **LED Light** – flashing LED light, in Buddy Tracker blue light means that someone is checking user's location (hardware specific).
- **Flashlight** – screen flashes a few times and then goes back to the previous state.
- **Vibration** – special pattern indicates a location-checking event.
- **Sound** – feedback is represented as a distinct musical tone playing when the event occurs or it can incorporate fully descriptive natural language feedback, e.g. playing synthesized or recorded speech: "*Bob is checking your location*."
- **Security alert** – special type of dialog box incorporating map visualization to convey richer feedback information. This type of visual feedback is used to display aggregated information in the event of unusual events, i.e. user X has checked Y's location 50 times in last two days (Figure 1c). This type of representation can be used to present both real-time and aggregated information.

In this section we presented a classification of feedback that we use in our research model for studying the role of feedback in privacy management for mobile location-sharing applications. We also presented example interfaces supporting our feedback classification. The work presented in this paper does not cover all possible variations of interaction, time and sensory dimensions. Here, we focus only on exploring implications of real-time feedback through automatic interaction on users' behaviour in Buddy Tracker, mobile location sharing-application.

4. BUDDY TRACKER ARCHITECTURE

Figure 2 illustrates our architecture for Buddy Tracker, a mobile location-sharing service that supports the three characteristics of *social translucence*: *visibility*, *awareness* and *accountability* by incorporating real-time feedback. Our application provides several options for managing privacy, which are described in section 4.3. Firstly we briefly describe technical details of Buddy Tracker and then present the functionality of the application.

[1] http://www.htc.com/www/product/g1/overview.html

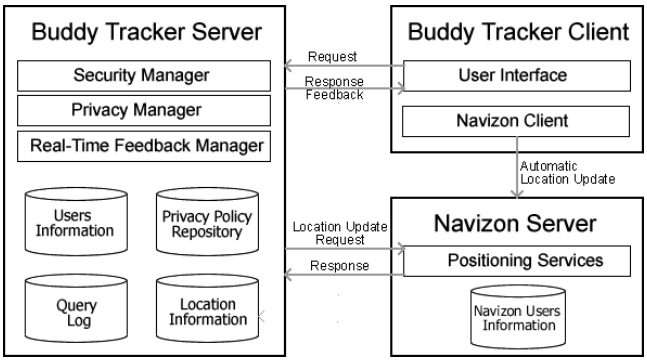

Figure 2. Buddy Tracker architecture.

4.1 Technical Details

We combined several separate services in our design, allowing us to develop prototypes quickly, deploy them automatically, and update services for users in the field without user intervention.

Our application uses the Navizon[2] service which updates our server every 10 minutes using the most accurate positioning system visible to the device at the time: GPS, Wi-fi, or cell-id. We found this service on the Apple iPhone to be the most accurate, easiest to set up, and had the best power economy of all of hardware and services we considered.

4.1.1 Buddy Tracker Client

The Buddy Tracker client application is implemented as a web application, which appears and functions much like a native application on the iPhone, using the jQTouch library[3]. The interface can be also used on other mobile devices which support WebKit[4] engine for rendering web pages, such as Google Android powered phones. This allowed us to activate and deactivate features instantly by changing the files on the server. It also allowed us to monitor usage of the system in order to send users instant experience sampling requests and to send real-time feedback to people whose location had just been viewed (a feature absent on all the other mobile location sharing services we considered).

A user of the client application (U1) sends a request to view the location of a fellow user (U2) to the Buddy Tracker server. The server generates a response containing U2's location information and sends it to U1. Additionally, the server generates a feedback response, which is sent to U2, informing them that U1 viewed their location. Both the data requester (U1) and data owner (U2) are users of Buddy Tracker client application. The diagram also shows the integration with Navizon server, which is being used as a positioning service in Buddy Tracker architecture.

4.1.2 Buddy Tracker Server

The server implements three modules (Security Manager, Privacy Manager and Real-Time Feedback Manager), and uses four data repositories (Users Information, Location Information Privacy Policy Repository and Query Log). The User Information repository contains information about users, such as their name, login, and password. The Location Information repository stores the users' positioning data as triple: time, location and user reference. Users' privacy preferences and real-time feedback preferences are stored in a Privacy Policy Repository and the Query Log contains information about location requests. This last repository is used by the aggregated feedback module provided in Buddy Tracker (Figure 5) to enable users to view who had accessed their location in the past.

We will now explain functionality of Buddy Tracker modules by illustrating an example location request, in which one user looks up location of another user in Buddy Tracker.

The first module that takes part in that request is the Security Manager; it is responsible for each user's authentication. After a successful check of a user's details in the Users Information repository, the location query is forwarded to the Privacy Policy Repository which analyzes the data owner's privacy policy. The system sends a response to the user based on requester's details and data owner's privacy policy. Information about the location query (data requester, data owner, location, granularity level of disclosed location) is then forwarded to the Real-Time Feedback Manager. The Real-Time Feedback Manager first checks the data owner's preferences for real-time feedback and then sends the feedback notification based on that information. Secondly, the Real-Time Feedback Manager saves the location request information in a Query Log for future reference.

4.1.3 Positioning service – Navizon Server

Buddy Tracker uses Navizon for user's location positioning, which provides a user's current location information. It is a third party service; therefore we had to develop a connector that integrates the Users Location repository with Navizon's database. Navizon is configured to update the user's position in it's server repository every 10 minutes. The Buddy Tracker server sends a request to the Navizon service at the same frequency and retrieves an XML file containing the user's location information.

4.2 Social Translucence in Buddy Tracker

Our main objective when designing Buddy Tracker was to support the data owner's privacy. To this end we have created a system that helps people understand each other's actions with respect to their privacy and social relationships. Buddy Tracker's architecture is grounded on the concept of *social* translucence, which has been highlighted as a method supporting awareness, a *shared knowledge* that enforces *accountability* by making people's actions *visible* one to another.

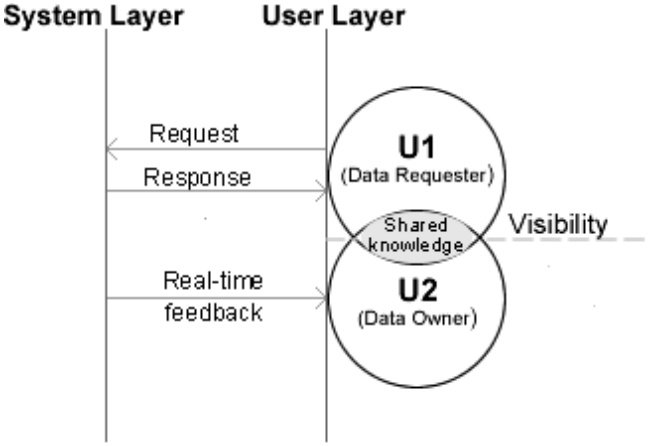

Figure 3. Social Translucence in Buddy Tracker.

[2] http://www.navizon.com

[3] http://www.jqtouch.com

[4] http://en.wikipedia.org/wiki/WebKit

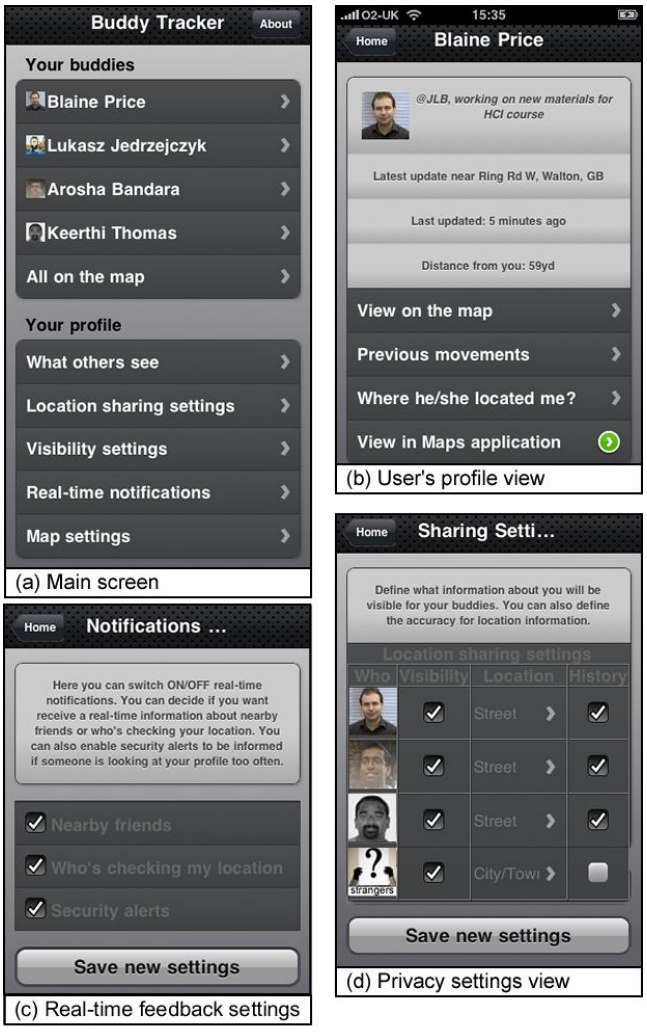

Figure 4. The Buddy Tracker application. (a) home screen view, (b) fine grained privacy settings, (c) real-time feedback appearance settings, (d) privacy settings.

We decided to use ad-hoc notifications in the form of SMS as method of providing *visibility*. Different alternatives for presenting feedback have been presented in section 3.4.

Every time a user of Buddy Tracker checks another user's location the system automatically sends a notification to the data owner, which informs him about every check made on his location. Because both the requester and data owner are aware of this notification process, the system also supports *awareness*.

Each location request is only temporal in nature, but the cumulative effect of these requests creates a context which affects the interpretation of each subsequent request. This context we call *awareness* or *shared knowledge*, which is gathered by the user through their longitudinal accumulation of experience. Our intention in supporting *social translucence* was to help people build their *shared knowledge* about others by providing *visibility*. Figure 3 shows how social translucence is introduced in Buddy Tracker.

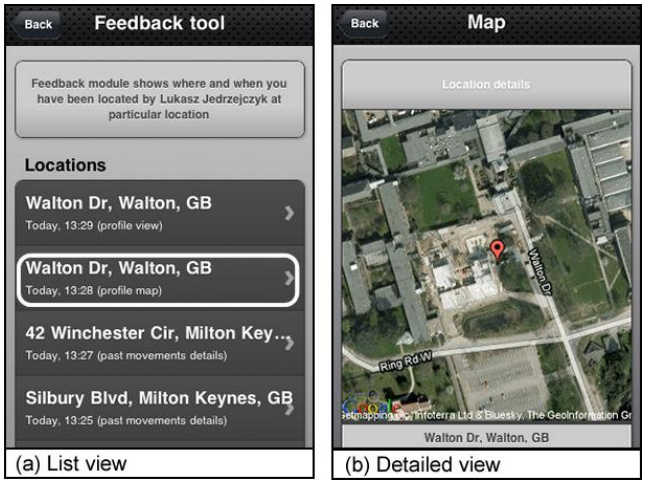

Figure 5. Aggregated feedback module in Buddy Tracker

4.3. User interface and basic functionality

The Buddy Tracker interface consists of two main areas, shown in Figure 4a. The first area, 'Your buddies' shows the list of all friends (Figure 4a) with link at the bottom of the list to the map, presenting all friends on a single map. Clicking on a buddy's name opens their profile (Figure 4b), with more detailed information about current location as a text description with a link to open an interactive Google Maps application. The second area on the main interface, 'Your profile', enables users to see how others see their profile, set location-sharing preferences (Figure 4d), define map preferences or set preferences for real-time feedback (e.g. notify me in real-time only if someone is looking at me too often, or if my friends are nearby, Figure 4c).

4.3.1. Privacy settings in Buddy Tracker

Our application provides several options for managing privacy, such as time-sensitive coarse-grained visibility (e.g., the user can make himself invisible for the next 3 hours) and peer to peer coarse and fine grained settings (e.g., the user can say that X can see his location only at city level). It also allows the user to define privacy preferences for strangers. We adapted our fine-grained privacy settings from Reeder's Expandable Grids [20] using a matrix layout.

4.3.2. Aggregated feedback in Buddy Tracker

Our application provides an aggregated feedback mechanism, which allows users to see who has viewed their profile, location or who accessed their location history. Every location request performed by system users is stored in the database together with time and location information. Users can then view all requests made by their buddies and see who has viewed them when and where. To convey that information we used a list visualization (Figure. 5a), similar to that used by Raento [14] and Tsai [7]. By clicking on the list item, users can view the location they were looked-up at, on the map (Figure. 5b).

5. EVALUATING REAL-TIME FEEDBACK

We conducted three studies aimed at exploring the role of real-time feedback for managing privacy in mobile location-sharing applications:

- A focus group discussion during which we presented the real-time feedback concept and explored its usability possibilities.

- In-depth interviews with users of location-sharing applications.
- A field trial of Buddy Tracker with the real-time feature to observe how the use of a socially translucent system affects user behaviour.

These studies helped us understand the reciprocal nature of feedback and have led to criteria for building a real-time feedback manager that meets social expectations.

The following sections describe the studies conducted, detailing our methods and findings with a discussion of our results. Joint results of all studies are presented in section 6 as high level design guidelines for designing real-time feedback, which we will use to develop a context-aware real-time feedback manager service.

5.1 Focus Group Evaluation

In order to gauge initial user reaction to the range of interface methods, we conducted a focus group evaluation of the 8 real time feedback notification methods suggested in section 3.4.

5.1.1 Method

We recruited 8 participants (4 males and 4 females) aged from 24 to 40, offering a free lunch as compensation for completion of the study. We posted information about the study on our university's intranet page (potential population approximately 5,000 administrative, clerical, and academic staff plus approximately 200 PhD students). The group comprised 6 PhD students from different backgrounds (computer science, psychology, chemistry) and 2 administrative employees of the university. The study lasted for 90 minutes. Although 4 participants said they had used location-sharing technology, none of them used it on a daily basis so we began the focus group with a short introduction of the Buddy Tracker application and the concept of real-time feedback. Participants were also presented with a working prototype of the real-time feedback mechanism.

During the next phase we presented the group with six different scenarios, showing examples of how our real-time privacy feedback works. Scenarios were presented in narrative form and were supported by videos. Based on our previous findings [21], we aimed to elicit a wider range of responses by designing the scenarios to present both positive and negative experiences. Figure 6 presents an example scenario showing both positive and negative reactions as the result of using real-time feedback. In the example scenario we highlighted the user's reaction as the measure of real-time feedback utility. By using both negative and positive scenarios we also hoped to stimulate people to think about the real-time feedback in the context of Bellotti and Sellen's [6] criteria for evaluating UbiComp systems, especially with respect to *intrusiveness*, *appropriate timing*, *unobtrusiveness* and *perceptibility*.

After the presentation participants were asked to choose the best real-time feedback representation for each of the scenarios. Users could assign one or more representations as the best choice.

5.1.2 Findings

All participants agreed that real-time feedback was necessary to some degree but none felt it was perfect. A common opinion was that it could help protect the data owner's privacy, but on the other hand, the nature of this technology is intrusive and needs to be really intelligent before it can be introduced in real applications. It was also suggested that "*people might stop using*

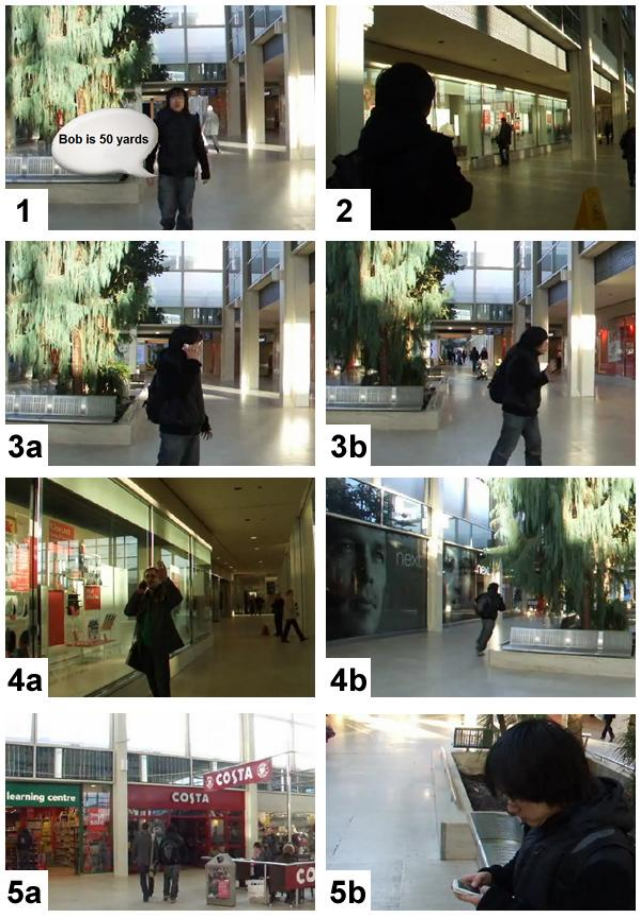

Figure 6. Stills from a video scenario presented during the focus group session. In this scenario Ed, a user of Buddy Tracker, is walking in a shopping mall. Suddenly his mobile phone plays synthesized speech: "*Bob, is 50 yards from you*" (1). Ed started looking around and noticed Bob looking in a shop window (2). In the *positive scenario* Ed decided to surprise Bob and calls his phone (3a). Bob, answered the phone, looked back and noticed his friend (4a). Both friends went into the coffee shop (5a). The *Negative* version of this scenario is slightly different. Ed, was very surprised that Bob is close to him (3b) and decided to hide behind trees (4b). Once he 'disappeared' in the physical environment he decides to hide himself in Buddy Tracker as well (5b).

the (location-sharing) technology if they knew that whatever they did was visible to others".

Another issue of the real-time feedback is that it could result in memory overload; one participant said that *"every time (someone) used it people might have a small, internal debate about 'should I do it?'"* On one hand, real-time feedback is desirable; on the other it is intrusive and decreases the comfort level of using the technology, both for data owner and data requester. The data owner might be interrupted with frequent annoying and incomprehensible messages and data requesters might stop using Buddy Tracker due to the transparency of technology.

Some participants suggested that real-time feedback would not be usable in the case of hundreds friends on a buddy list. They could not see the point of using real-time feedback for each friend, and

suggested an option to define which friend/group of friends triggers real-time notifications. Participants also highlighted a need for aggregated feedback, which enables people to check who accessed their location information even if they missed a real-time notification. It has been also suggested that aggregated information about location requests could be used to automatically protect location information in a case of unusual usage, i.e. when someone tries to access location information of one person too often. Based on number of requests system could recognize unusual usage pattern and automatically decrease accuracy of location.

5.1.3 Discussion

The underlying concept of social translucence in Buddy Tracker was to support privacy and increase the comfort of data owners in sharing their location. Our goal was to enforce *accountability* by providing *visibility* and *awareness* in the form of a timely and meaningful notices delivered via the mobile device. All participants agreed that the concept itself has a potential to protect privacy, but several conditions must be met before real-time feedback meets social expectations. Feedback representations presented during the study provided a set of rich interfaces, which in the opinion of participants, might help real-time feedback technology become an everyday thing, such as a new SMS notification. However, the usability of interfaces is only one part of technology adoption. The key to the success of real time feedback is context-awareness and intelligence; otherwise the balance between its utility and cost cannot be preserved. Although this was a small study with a slight bias toward academics, it suggests that it is important that real-time feedback should enhance a system such that it provides meaningful information in the most appropriate way for a given context. Our participants also highlighted the need for the aggregated feedback, i.e. social translucency cannot be achieved by the real-time feedback only, it has to be supported by the aggregated feedback such as a disclosure log (e.g., Figure 5).

The focus group session helped us identify possible implications of using real-time feedback technology and highlighted usability problems of both the real-time feedback concept and proposed interfaces. This study also helped us draw an agenda for our studies on real-time feedback.

5.2 User Interviews

Comments from focus group discussions were very useful and helped us define the future path for studies on the real-time feedback concept. However, those participants based their views on a theoretical understanding of the technology rather than practical experience. To balance this, we interviewed active users of real location-sharing technologies to compare their opinions with the focus group results.

5.2.1 Method

We interviewed 5 active users of location-sharing services, aged from 15 to 35, three males and two females. We approached people directly by sending private messages to nearby people on two different location-sharing applications (Brightkite and Foursquare). We also posted requests on social networking sites, inviting experienced users of location-sharing applications to participate in our study.

Interviews lasted between 40 and 90 minutes and were structured similarly to the focus group discussion (introduction of the real-time feedback concept, presentation of interfaces, presentation of scenarios, task - choosing the best representation for given scenario, free discussion).

5.2.2 Findings

Four participants said that the technology would definitely have an impact on their behaviour, and would stop curious people from making unreasonable location tracking actions. This corresponds to findings of the focus group discussion. The remaining participant said that real-time feedback would not have any impact on users' behaviour at all.

All participants said that real-time feedback should work accordingly to the current state of the mobile device, e.g. do not use sound or vibration if phone is in the silent mode. An easy ON/OFF option and time sensitive settings were suggested as a method of avoiding distractions, especially at work. Some participants also suggested that they would like to be reminded about location look-up in next few minutes if there was no acknowledgment from them to the feedback. Another factor determining user's preferences for real-time feedback representation is mobile activity. Our participants reported that their preferences may be different when writing an SMS, playing a game or watching a video on their mobile device. E.g. toast has been recognized as a good method of providing feedback while browsing the Internet.

Changes in behaviour or distractions were not the only negative social implications of real-time feedback noted: participants were also concerned about disturbing other people, especially when using vibro-tactile and auditory representations.

5.2.3 Discussion

All participants expressed interest in the real-time feedback technology and willingness to use it. Participants offered positive comments about the ability to control their data. It was perceived as a monitoring tool that empowers users, giving them the full control over the information generated. Like the focus group participants, interviewed participants expressed their concerns about the intrusiveness of the technology. *Appropriate timing* and *unobtrusiveness* seem to be two main criteria affecting both the acceptance and level of comfort when using technology. Meaningful and timely information are the key factors determining trust in the technology. Other factors, such as *perceptibility*, *flexibility or low effort*, were also highlighted during interviews, however did not raise as many concerns as *appropriate timing* and *unobtrusiveness*. These findings suggest that work on the real-time feedback should not be focused on designing new interactions and interfaces, but on the context-aware real-time feedback manager service, which decides how to tailor feedback to the user.

5.3 Buddy Tracker Field Trial

We performed a field trial of Buddy Tracker to enable us to examine the usage of real-time feedback in a realistic scenario. Real-time feedback was delivered as a text message (i.e. a SMS message) sent to the tracked person, immediately after they had been looked up. The message took the form "[X] has just looked up your location", where X was substituted with the relevant user's name. In comparison to the mobile interface elements described previously (Section 3.4), this form of feedback is closest to the dialog box element, incorporating elements of audio and vibro-tactile feedback depending on the user's device configuration for SMS notifications.

Decision for using SMS as a method for delivering real-time feedback was dictated by the low level of context-awareness in the current set-up of Buddy Tracker. Lack of support for *appropriate timing* and *unobtrusiveness* could cause potential harm to our participants therefore we could not test different feedback representations (presented in section 3.4) at this stage. In this study we were focused on eliciting end-users's requirements for real-time feedback.

5.3.1 Participants and devices

In section 4 we described the basic technical design of our Buddy Tracker prototype. After evaluating a number of Smartphone platforms we chose to implement our first prototype on the Apple iPhone, as it was the only device where we could get constant (every 10 minutes) automatic monitoring at a high level of accuracy (GPS/WiFi/Phone Cell) without depleting the battery before the end of one day.

We recruited two groups of participants all of whom were experienced iPhone users in order to reduce Hawthorne and training effects. The first group consisted of 7 people centered on one family (age range 17 to 52) with three young adult children and the partners of the two older children. The second group consisted of 5 people and was centered on a second family (age range 20 to 48) with two young adult children and a long-standing, close family friend. Each participant only had access to the real-time location data for all the other members of their own group.

5.3.2 Method

We advertised the study through various mailing lists and by word of mouth asking for volunteers in a close social, family or work group, where all members of the group used an iPhone. Participants were told that they would use the Buddy Tracker prototype and allow us to monitor their activities, specifically any exchanges and interactions taking place between them and co-participants over a period of three weeks. We explained that we would send short experience sampling requests after each use of the system in order to collect data about motivation for any location tracking events. We also explained that we had instrumented the interface to collect information about any tracking events. Participants were offered £65 (approx $100) for completing the 3-week study including pre- and post-study interviews, each lasting 90-120 minutes.

The study consisted of three phases of one week each. In the first two phases, the participants had no privacy controls to protect their location and were free to use others' location information as they wished. In the second week, participants were given tasks such as investigating the location of co-participants and, based on that information, make inferences on what they are up to. In the final week, we gave participants privacy controls, including an interface for setting coarse and fine grained location-sharing preferences (granularity control) as well as aggregated historical feedback and real-time feedback.

5.3.3 Findings

Over the period of 3 weeks 12 participants used the Buddy Tracker application 746 times (an average of three times/day/participant). We noticed only 81 views of the Buddy Map (showing all members of the group on a single map). Our participants preferred to check location of their friends individually using their profile. We found that user profiles (showing a text description of the user's location) were checked 668 times and of these the participants drilled deeper 305 times to look closer at the precise location of a buddy via map, which can be accessed from the profile view (Figure 4b). Participants did not indicate much interest in past movements of their friends; we recorded only 4 list views of past locations by a single member in the second group and no others.

Managing Privacy

Our participants did not use any of the privacy interfaces provided by Buddy Tracker with the exception of a few cases when they were specifically asked to do so during phase three of the study. When asked about using privacy interfaces in the post-study interviews, participants said that they did not change their privacy setting for a number of reasons:

- **Social familiarity and closed-group setting:** Some users did not feel the need to change privacy preferences because co-participants were members of their family or close friends and they had nothing to hide from them. Moreover, participants knew it was an experiment and their data were only accessible by specific group of people.
- **Risk of misunderstanding:** Some of our participants also said that changing privacy preferences would not be a good idea because other people would make inferences about the intent of not sharing everything within the social network, which might cause unpleasant situations and affect their relationships. One participant said that "*If I had used privacy settings my mum would be upset"*. From their perspective, turning on privacy settings in an advanced stage of the study was like changing rules during a game.
- **Lack of familiarity with interface:** Another reason given for not setting privacy preferences was that peopl**e** did not have access to the interface for doing this (Figure 4d) until phase three, and did not have sufficient opportunity to explore its functionality.

Of these, the main reason for not setting any location-sharing privacy preferences was the first category, i.e. the experimental nature of the study coupled with the close relationship between the participants.

Social implications of Feedback and Privacy Protection

The post-study interviews revealed that data owners, that is, those about whom location data was requested, were neutral about feedback. Knowledge about who had accessed their location made them neither more or less willing to share their location information. Three participants said that they would not like to use real-time feedback in a real location-sharing application. The main reason given was that it starts to make the feedback recipient think about the motivation for the data requester, which can lead to false inferences, therefore people would like to avoid these situations by not knowing.

The perspective of the data requester is different, however. During interviews we found that that real-time feedback can have an impact on the data requester's identity and how their social networks perceive them. Participants also suggested that the information delivered in real time could shift one's position within the social network due to (wrong) inferences made by the data owner about the data requester.

We asked our participants if the visibility provided by real-time feedback affected their use of technology or comfort level of using it. They reported that feedback had a strong impact on how they used Buddy Tracker after it was introduced in the third

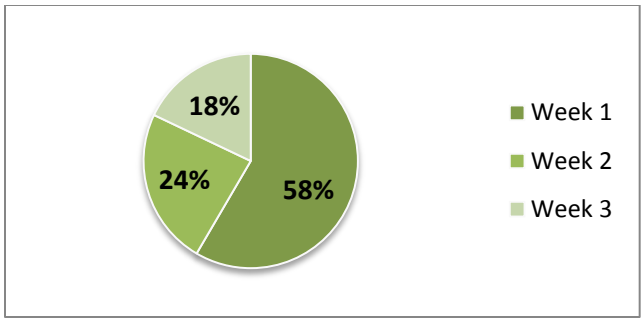

Figure 7. Pie chart showing frequency of tracking events made by Buddy Tracker users during each phase of the study as a percentage of all events.

phase. When a participant was asked if she would have repeated a tracking action she did in Phase 2, when there was no feedback, once the feedback feature was activated she said "*I wouldn't have done it if I knew the person knows*". This demonstrates how real-time feedback introduces a "Should I do it?" debate in the user's mind, inhibiting tracking actions when there is no justification for them. Only one person (a mother from the smaller group) explicitly said that real-time feedback has no impact on how she used Buddy Tracker. However, she felt it was her instinct as a mother to check on members of her family frequently to protect them and if they received feedback about it then it would only reinforce that she cares about them. The mother in the larger group also reported that her use of the technology was to protect her family rather than voyeuristic.

In order to look at how real-time feedback affected the usage of Buddy Tracker we also looked at the frequency of occurrence of the following two events: (1) checking buddies' location on a map and (2) viewing buddy's profile. We observed that the total number of each type of events in phase three was smaller than in the first phase (Figure 7). Although the larger number of events in phase one might be due to the "*play*" effect, data collected during interviews confirm that smaller usage of Buddy Tracker in phase three is the consequence of participants deciding to refrain from making location requests which they would find hard to justify had they been held accountable by the other party.

Participants reported that the feedback did not stop them using the application but it made them think that they should have a good reason for using it: people are more accountable for their actions, which limits the number of unjustified tracking events.

Feedback Adoption

Although real-time feedback can be successful both in raising social awareness and preserving privacy, it has several disadvantages that were highlighted during interviews.

From a social perspective the biggest issue with real-time feedback is that people make inferences that can result in wrong judgments and also might affect social relationships. When deciding whether to locate someone, a requester has to deal with issues pertaining to motivation and responsibility, which a data owner does not have to do. When making location request, certain conditions need to be met in order to (internally) justify the action. The purpose of that "*Should I do it?*" debate is of course not to think about the possible harm or other people privacy, but to protect the person's own position within the group.

We found that the "internal debate" takes places also in data owner's head. One of our participants told us that feedback made her ask questions such as "*Why did X look at my location? What does he want?* ". It shows that feedback might overwhelm some users with information, which results in inferences that can affect relationships.

5.3.4 Discussion

Although this is a small study with a limited demographic, these initial results suggest that real-time feedback is a good mechanism for supporting one's location privacy. Our observations show that real-time feedback in the form of SMS messages can be used to build a social translucent location service, in which the privacy of others is respected by providing *visibility*, *awareness* and *accountability*.

The introduction of real time feedback in the final week had a definite effect on the participants' use of the system; it did not stop them but it did limit usage to the situations where they felt they had an obligation from the data owner to check his location.

Our study indicates that one's privacy can be protected with little to no effort by making things visible one to another. We showed that visibility, which has been represented in the form of real-time notifications, resulted in better *awareness* of the extent to which the system works. We also proposed an architecture for a mobile location-sharing service, which is based on the concept of social translucence. We provided both quantitative and qualitative data to show that this architecture successfully enforces accountability and limits the number of unmotivated and unreasonable location requests, which in consequence helps preserve one's privacy.

Although our participants did not change their privacy settings we suggest that this may be an artifact of the participant group types: both were very close extended families. Further studies involving peer groups and work relationships as well as more distant families are necessary before any further conclusions can be made about the utility of privacy settings.

Our study revealed a number of interesting phenomena about protecting privacy within the spectrum of a location-sharing service. We found a positive impact of social awareness on location tracking activities and privacy protection. However, our groups were limited, both in terms of diversity and social relations and in terms of number so further studies are clearly needed.

This study has shown that real-time feedback does not only affects users' behaviour and activities within the system, but can also impact relationships in the real world. Participants did not stop using Buddy Tracker after real-time feedback was introduced, but its invasiveness and obtrusiveness has been reported as an important issue. The study provided both quantitative and qualitative data to confirm a positive impact of real-time feedback on data owners' privacy, although we were not able to show that feedback has an impact on data owners' perception of control. We suspect this is due to the close relationship of participants we chose.

6. HIGH LEVEL DESIGN GUIDELINES FOR REAL-TIME FEEDBACK

Our studies have shown that real-time feedback is a desired option, which has a positive impact on users' privacy. At the same time technology needs to meet number of *social criteria* in order to be accepted. The invasive nature of real-time feedback technology has been recognized as the main barrier for this technology to be unobtrusively embedded. To help designers of mobile location-sharing applications get better insight into the how real-time feedback should be incorporated into the

technology, we present the results of our studies as a set of high level design guidelines. We used Bellotti and Sellen's [6] criteria for evaluating ubiquitous services as a framework for presenting our results and highlighting the future direction of our research.

Trustworthiness: *Systems must be technically reliable and instill confidence in users. In order to satisfy this criterion, they must be understandable by their users. The consequences of actions must be confined to situations which can be apprehended in the context in which they take place and thus appropriately controlled*. While Buddy Tracker supports both coarse and fine grained privacy controls, setting privacy rules is not mandatory and users can also make their profiles fully open which makes their data available to all users of the system. *Visibility* and *awareness* supported by real-time feedback are crucial to achieve *accountability*, as the factor supporting privacy of location information. Junglas highlights that *trust in technology can result from the consumer's perception of being in control* [22] therefore users that decide to use real-time feedback must feel that their privacy is protected and they are in control of their data. In other words, they are aware of who has access to their location information and they have an option to disconnect others by creating appropriate privacy rules.

Our studies have also shown that real-time feedback has to be supported by aggregated feedback information, which enables people to check who accessed their location even if they missed a real-time notification.

Appropriate timing: *Feedback should be provided at a time when control is most likely to be required and effective*. Buddy Tracker automatically notifies users about each location request made on them, which sometimes can annoy users and lead to the uncomfortable situations. Our studies revealed that users' willingness to receive a notification depends on the context, which incorporates several factors, such as time, location, activity, phone's position, company and importance of the information. We found that *mobile activity*, which we take as a current task performing on the mobile device (phone call, writing SMS, browsing web), is an important factor deciding about people preferences for feedback representation.

Perceptibility/Unobtrusiveness: *Feedback should be noticeable. Feedback should not distract or annoy. It should also be selective and relevant and should not overload the recipient with information.* It is well known that too much privacy or security feedback numbs the user into ignoring it or switching it off. Buddy Tracker provides feedback representations in different dimensions, which conveys timely and meaningful information in both noticeable or more discrete form, depending on the context. Designers should use all available contextual information to provide feedback in a most visible and unobtrusive form.

Our studies have also shown that people would like to be reminded if there was no acknowledgment from the user to the feedback. A good example of this practice is a snooze function in alarm clock; or SMS delivery service in Apple iPhone, which notifies about new text message again few minutes later after delivery time if user has not read it.

Minimal intrusiveness: *Feedback should not involve information that might compromise the privacy of others.* The underlying concept of real-time feedback is to support awareness by providing simple message *"X just looked up your location".* Therefore it is important not to provide too much detail about a requester, because it might affect his privacy. Real-time feedback in Buddy Tracker never discloses private information about the data requester, except name or pseudonym used in the system. It also depends on the feedback sensory representation used in a particular situation. Our studies revealed users' concerns related to using fully descriptive natural language auditory feedback in public places.

Fail-safety: *In cases where users omit to take explicit action to protect their privacy, the system should minimize information capture, construction and access.* An automatic hide/blur function for protecting one's privacy has been suggested during the focus group study. Based on the unusual usage pattern identification system could automatically hide or blur one's location, which can improve users' comfort for using location-sharing applications. In the basic scenario, automatic hide works as user agent which helps negotiate location requests based on the information about relation, data flow and user's previous actions. E.g. if the user A is notified X times that another user B is looking up his location and if no explicit action is performed to prevent, ignore or continue that, the system automatically changes A->B privacy settings until A says differently. We currently work on the new version of Buddy Tracker, which will integrate this functionality. Automatic hide also contributes towards the low effort criterion, as it can help users justify their privacy preferences automatically.

Flexibility: *What counts as private varies according to context and interpersonal relationships. Thus mechanisms of control over user and system behaviours may need to be tailorable to some extent by the individuals concerned.* Buddy Tracker allows users to define whether and when they want to be notified in real time about particular event. Users have option to switch real-time feedback ON or OFF (Figure 4c). Real-time feedback should work accordingly to the current mode of the mobile device, which minimizes the risk of disrupting users in their daily tasks and provides easy switch ON or OFF option for less discrete representations.

Low effort: *Design solutions must be lightweight to use, requiring as few actions and as little effort on the part of the user as possible.* In most cases real-time feedback does not require any effort from users. The underlying concept behind the feedback is to support awareness and understanding by providing timely information, although, some representations require user interaction (e.g. dialog box needs to be closed by the user). We found that feedback representations that require an action from the user are considered as more annoying.

Meaningfulness/Learnability: *Feedback and control must incorporate meaningful representations of information captured and meaningful actions to control it, not just raw data and unfamiliar actions. They should be sensitive to the context of data capture and also to the contexts in which information is presented and control exercised. Proposed designs should not require a complex model of how the system works. They should exploit or be sensitive to natural, existing psychological and social mechanisms that allow people to perceive and control how they present themselves and their availability for potential interactions.* When designing for social awareness it is important to deliver meaningful information in an understandable manner. The real-time feedback interfaces presented in section 3.4 make use of the known mobile interaction metaphors, such as sound, vibration or different types of visual elements, including programmable hardware features to enrich the user experience. In the most basic form, real-time feedback just conveys a standard message on the

screen, such as "X is checking your location". Other interfaces, such as assigning a specific tone to this event, function the same as from the familiar assigning of a unique ringtone to the contact.

Low cost: *Naturally, we wish to keep costs of design solutions down.* Designing for real-time feedback is not an expensive task, as the message is simple. Our implementation uses well-known mobile interaction metaphors and GUI elements. However, the disadvantage is that some of the interfaces we developed work only on specific platforms. For example, the notification bar and LED works on Google's Android powered devices and are absent on Symbian and Apple devices.

7. CONCLUSIONS AND FUTURE WORK

We proposed real-time feedback as a means for providing *visibility, awareness* and *accountability* in Buddy Tracker, a mobile location-sharing service. We argued that real-time feedback helps protect one's privacy by incorporating *accountability*, which reduces the number of 'unjustifiable' location requests. From our lab based evaluation, interviews and three weeks field investigation of Buddy Tracker we provided both quantitative and qualitative data to support the above hypothesis.

We have not observed any correlation between the knowledge of being tracked and changes in locations sharing rules. We believe this was due to the close relationship of our chosen participants. One of the lessons from our field evaluation is that restricting participants to a family-related group limited the scope of the data we collected.

Although our work suggests that real-time feedback is a positive feature in terms of supporting one's privacy, there is clearly much more work to be done. We have designed several sensory representations of real-time feedback, which provide a diverse range of warnings for a given context. However we could not test them all because at the time of conducting our field trials, Buddy Tracker did not support *appropriate timing*, which has been recognized as a crucial element for the acceptance of this technology. Therefore we decided to use SMS only as a method of providing real-time feedback since it was a familiar interface and needed no training.

Real-time feedback is an invasive technology, which can become another annoying security feature that is quickly dismissed by users. Therefore it is important for us to explore how to convey meaningful information in the most appropriate way for a given context. We have already started collecting data about users' real-time feedback preferences in different scenarios, which will be used to inform the design and development of a context-aware real-time feedback manager service [23]. We are also working on a machine learning method described in [24] to automatically adapt the most appropriate real-time feedback representation for a given context based on knowledge from observational data. Once completed, this will enable us to repeat the study with a wider demographic and evaluate all the feedback representations we identified.

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