

ACCESSING DATA: METHODS FOR UNDERSTANDING MOBILE TECHNOLOGY USE

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ABSTRACT

Mobile devices, applications and services have become integrated into people's daily lives on a personal and professional level. Although traditional research methods are being used to understand the use of mobile devices and applications, methodological challenges still exist. Researchers have responded to these challenges in a variety of ways, with an emphasis on developing methods that enable new ways of accessing, making available and collecting data about mobile technology use. This paper identifies, defines, describes and presents, a preliminary framework for understanding the methodological responses emerging in current Mobile Human Computer Interaction (Mobile HCI) research.

INTRODUCTION

Traditional methods, such as direct observation, used in Human Computer Interaction (HCI) and Computer Supported Collaborative Work (CSCW) research are commonly applied and adapted to mobile environments. However, variations and new methods are emerging in response to the particular challenges of mobile technology use. These result from both the complexity that physical movement and changing variables present for data collection and research design (Kjeldskov and Stage, 2004) and the small scale and ubiquitous nature of mobile devices. For example, observations of mobile technology use can require researchers to follow people to various and multiple geographic locations, such as into confidential meetings (Väänänen-Vainio-Mattila and Ruuska, 1998), trips to the movies or the park, business trips (Perry, O'Hara, Sellen, Brown and Harper, 2001), on shopping excursions (Newcomb, Pashley and Stasko, 2003) and into the bedrooms of teenagers (Grinter and Eldridge, 2001) or long distance lovers (Kjeldskov, Gibbs, Vetere, Howard, Pedell, Mecoless and Bunyan, 2004). The very nature of mobile devices means that we carry them with us and we use them in a number of ways and situations both professionally and personally.

This paper contributes a preliminary framework for understanding the emerging methodological responses to the challenges of studying mobile technology use. This framework sets out the array of traditional, modified, novel and combined approaches currently being used by researchers in the exploration, evaluation and design of mobile devices. By gathering, grouping and describing the methodological options currently being exploited, our intention is to encourage and support further research and to offer a tool for interested parties to exploit as they design and develop their own projects. In particular, we have identified the issue of gaining and negotiating access to data as particularly significant for studies of mobile technology use. This is due to the variety of times, ways and places in which use occurs and the personal scale of mobile devices. As a result, many of the ways in which established research methods are being extended account for the difficulties of accessing and collecting valid data in mobile situations. Furthermore, we found that traditional

approaches, such as ethnography and field studies, are being rethought—not in terms of their approach, motivation or theoretical commitment—but in terms of the methods used to achieve them.

In their review of Mobile HCI research methods, Kjeldskov and Graham (2003) found very few examples of studies of actual use in real settings or of conceptual and theory building research. Our work builds on and extends the contribution of Kjeldskov and Graham. However, this paper differs in that it explores new methodological approaches that are emerging in response to the complexities of mobile technology research, rather than categorising approaches according to existing methods. Also, Kjeldskov and Graham differentiate between methods based on their research purpose, for example, to evaluate, to understand or to describe. Although we are aware that these are different processes and certain methods lend themselves to different stages of the design cycle, accessing and collecting data is a challenge that faces researchers irrespective of their research purpose. These overall issues of making data available, whether for analysis, representation or to inform design, are the foci of this paper.

LITERATURE SEARCH

This paper is based on an extensive literature review of papers that reported on methods for studying and evaluating mobile technologies from the following conferences between the years 2000 and 2004 (Hagen et al., 2005):

- Conference on Human Factors in Computing, CHI, ACM
- Conference on Computer Supported Cooperative Work, CSCW, ACM
- Symposium on Designing Interactive Systems DIS, ACM
- International Workshop on Wireless and Mobile Technologies in Education, WMTE, IEEE
- Symposium on Human-Computer Interaction with Mobile Devices, Mobile HCI, Springer
- Participatory Design Conference, ACM
- Conference on Ubiquitous Computing, ACM
- Conference on Mobile and Ubiquitous Multimedia, MUM, ACM
- Conference of the Computer-Human Interaction Special Interest Group of the Human Factors and Ergonomics Society of Australia, OZCHI

One hundred and forty nine papers, reporting aspects of studying use, were selected as relevant to our review. Papers were included in the review if they had substantial focus on aspects of the use of mobile technologies. Hagen et al., 2005 provides a full list of papers reviewed in the initial research including an annotated bibliography. In addition, we also draw here on more recent publications from these conferences, as well as other major reviews, critiques and comparisons of mobile methods in published literature and theses. There is a significant existing body of work available on lab-based methods for mobile research (e.g. for an extensive survey of lab based studies of mobile technology use see Beck, et al. 2003; also Kjeldskov and Stage, 2004; Po et al. 2004; Pirhonen et al. 2002). Rather than replicate this work, our original literature search focused on those research methods used to study mobile technology use in real settings. We should note here that any discussion on research methods is constrained both by a lack of consistency with which methods are

named and considered within the human-centred design literature, as well as by the frequent lack of availability of detailed accounts of the method used. We have compensated by the breadth of our survey and by cross-referencing similar work by the same authors and related research by others.

METHODOLOGICAL CHALLENGES

Many of the complexities related to gathering data about mobile technology use stem from the fact that we are no longer attempting to gather data in a fixed office environment. As researchers we need to account for the potential for physical movement and changing geographical location of users. But we also need to negotiate access to private and public spaces that are not defined by the rules of the workplace. For example, researching people's shopping habits in order to design improved mobile shopping assistants (Newcomb et al., 2003), understanding how groups of friends might use an SMS chat application to rendezvous at a particular location (Axup, Viller and Bidwell, 2005), or gaining insight into why and how teenagers might use a mobile device to interact with an existing virtual community (Still, Isomursu, Isomursu and Koskinen, 2002).

Direct observation, which can include note taking, photography and video recording, has historically been favoured by user centred design researchers because it is a method that situates the researcher in the context in which technology use occurs. However, environments of mobile use are not always conducive to these methods. For example, researchers following people around shopping malls with conventional video cameras can be disruptive as members of the public may stop and stare (Isomursu, Kuutti and Väinämö, 2004) and shadowing participants at the same time as trying to take notes can be rather impractical (Palen and Salzman, 2002). In addition, mobile devices are designed on a personal scale for relatively discrete use within our personal body space; a mobile phone or PDA is intended to be used by one person at a time. Therefore, capturing or analysing the interface actions of the user, or observing a devices screen, can be physically very difficult (Kjeldskov et al., 2005; Newcomb, et al., 2003; Mark, Christensen and Shafae, 2001).

Furthermore, mobile devices, particularly personal communication devices, are having a significant impact on the ways in which we coordinate, communicate and conduct our daily lives (Rheingold, 2002; Plant, 2001; Harper, 2003; Ito, 2005; Ling, 2004). Such devices contribute to the constant reshaping of our body image and the constitution of new and evolving socio-technical relationships and identities (Ito, 2005). As hosts to mobile technologies, our bodies become integrated into evolving information and communication systems (Viseu, 2003). Research into mobile technology use crosses boundaries of the personal, at a physical and conceptual level. These types of research environments require balancing the privacy concerns of participants with the need for researchers to gain access to data. While in this paper we focus on methods for access and collecting data about mobile technology use, we advocate and support continuing work into a broader methodological questioning and investigation that considers what it actually means to be conducting research in such environments and the types of methods that are appropriate.

METHODOLOGICAL RESPONSES

Researchers are responding to the methodological challenges of access by extending and combining existing methods and developing novel techniques. We have grouped the emerging responses under the following three categories:

1. Mediated Data Collection. Access to data and data collection about use in natural settings are mediated by participants and/or mobile technologies. This happens in three basic ways:
 - Do it: participants actively collect the data.
 - Use it: data collection occurs automatically as a side effect of using the technology.
 - Wear it: participants carry or wear the data collection device.
2. Simulations and Enactments. Data about use is made available through forms of 'pretending' that encompass aspects of real use situations.
3. Combinations. Existing methods and/or mediated data collection and/or simulations and enactments are combined to allow access to complementary data.

Table 1 provides a summary of the approaches, identifies established methods from which these approaches are derived and supplies examples of their use. For reasons of space we have allocated a number for examples; the number corresponds to the numbered reference list at the end of this paper.

Approach:	Description:	Derived from:	Examples
Mediated Data Collection	Data about use in naturalistic settings is collected via participant and/or technology.		
Do it	Participants collect data using mobile devices.	Self-reporting, diaries, probes	[26, 27, 31, 53]
Use it	Data about use is collected automatically as the device is used.	Use/data logs	[15, 20]
Wear it	Data is collected automatically via devices worn on or by the participant.	Video observation, use/data logs	[30, 38, 46]
Simulations and Enactments	Data about existing or potential use is accessed through pretending and/or imagination.		
Simulations	Physical, ergonomic or environmental props are used to simulate physical aspects of use.	Lab tests, heuristics, prototypes, NASA TLX, emulators, simulators, scenarios	[7, 8, 19, 38]
Enactments	Role-playing, imagination and storytelling are used to explore potential use, often in situ.	Scenarios, role- playing, prototyping, work shopping, story boarding	[29, 46, 54]
Combinations	Various established and/or new methods are combined to enable access to complementary data.		[2, 12, 13, 14, 15, 22, 60]

Table 1. Emerging Research Methods in Mobile HCI

Mediated Data Collection: Do It

Mobile HCI researchers are employing self-reporting methods such as diaries and cultural probes (Gaver, Dunne and Pacenti, 1999) to access data about users' experiences and activities. In self-reporting, participants take on the role and responsibilities of data collection. For example, Grinter

and Eldridge (2001) conducted a study into how teenagers used text messaging using a diary method. Participants were not comfortable with being observed and instead were asked to log their SMS activities in a hand-written diary. This self-reporting method gave the researchers access to data where conventional direct observation was not appropriate.

Cultural probes and diaries have also been augmented through the use of mobile technologies themselves as reporting tools. Mobile Probes (Hulkko, Mattelmäki, Virtanen and Keinonen, 2004), SMS Probes (Jönsson, Svensk, Cuartielles, Malmborg and Schlaucher, 2002) and Experience Clips (Isomursu, Kuutti and Väinämö, 2004) are all self-reporting methods that employ mobile technologies as data collection tools. For example, Hulkko et al. (2004) developed Mobile Probes as a way for participants to document their shopping experiences using the in-built camera and SMS functions of their mobile phones. This information was automatically uploaded to a server that displayed the users' reports online in a predefined format. Hulkko et al. outline the advantages of such methods as: "...the possibilities to remotely and simultaneously observe several users, to automatise the sorting of the data and to create digital user databases for the stakeholders. Furthermore, users can become more active contributors instead of being only passive sources of data" (p 2).

In addition, these types of self-reporting, mediated data collection methods have also been used to evaluate aspects of user experience and usability for new prototypes in the field, e.g. (Isomursu et al., 2004). Self-reporting methods simultaneously build a relationship between researchers and the community that they are studying and/or designing for, and enable remote data collection. The limitations and constraints of such methods include: the possibility of users having to learn new interfaces or technologies to operate self-reporting devices (Jönsson et al., 2002; Palen and Salzman, 2002); the implications of participant-recording in inappropriate places such as shops where photos/video are often prohibited (Hulkko et al., 2004; Newcomb et al., 2003); and the impact on indirect and/or involuntary participants when their activities are recorded without permission. Further research is required to understand the research implications, as well as the potential, of such self-reporting methods for use in private or sensitive spaces. In the Discussion section below we briefly expand upon some of the ethical questions posed by the use of remote digital technologies as data collection tools.

Mediated Data Collection: Use It

The Use It mode of mediated data collection relies on the automatic generation of use or data logs. Researchers and participants are relieved of the burden of data collection as data and metadata about use is automatically generated as a side effect of using the device. For example, Curtis et al. (2002) developed a tool to log and time-stamp the actions of students using a handheld device as part of their learning program. Curtis et al. (ibid.) attributed the success of their research to the in-depth analysis that could be supported by a complementary combination of log files, student artefacts and observation.

Use logs have always been available to digital technologies, but technologies such as Bluetooth add new dimensions to what, and how, information can be logged (Eagle and Pentland, 2005). For example, there are platforms such as AWARE (Aware, 2005), which filter SMS messages based on location and proximity information. Cell tower IDs can give a user's location and Bluetooth can identify the other active devices that were nearby at the time the SMS was sent. While these methods are subject to similar ethical concerns as self-reporting methods that employ digital technologies, this approach also poses its own issues for consideration. Automated data collection methods differ from methods in which users volunteer information. Although users initially give permission to have

their actions recorded, they may decide later that they want to exempt certain actions. Understanding and determining best practice for these emerging tools is ongoing. Such concerns also apply to data collection tools that are worn by the participant.

Mediated Data Collection: Wear It

Data collection can also be mediated by mobile technologies that participants wear, or carry. Mini cameras are one such tool. As with Use It mode, data collection occurs automatically as people go about their daily activities. Mark et al. (2001) designed a mini camera that attached to a pair of glasses worn (along with a battery pack) by the participant. This method enables a form of remote video analysis and overcomes the impracticalities of following workers to various different locations. However, limitations include the length of time people can comfortably wear such devices, and whether the content that is captured provides enough peripheral information.

Mini cameras have also been used as a way of capturing screen display and interface actions that are hard to observe due to the small personal scale of mobile devices. In a field study of nurses using handheld devices, Kjeldskov, Skov, Als and Hoegh (2004) combined conventional and mediated data collection methods. A mini camera was attached to the handheld device and a microphone recorded the nurses' comments. The small camera was able to capture high-resolution video of the screen display and interface data, which was sent over a wireless network to a researcher in range. The mini mobile recording devices enabled the capture of high-resolution video of the device itself, while also facilitating the collection of data at a level appropriate to the environment. The videoing of patients in a hospital setting is almost always ethically inappropriate; therefore a conventional video camera could not have been used. The mini camera method enabled the capture of very specific video data relating to the use of the mobile device while preserving the privacy of the patients.

Remote sensor driven technologies are also being developed to overcome issues of access that exist when studying mobility, and mobile device use. For example, Intille, Tapia, Rondoni, Beaudin, Kukla, Agarwal, Bao and Larson (2003) are seeking to improve observation techniques through various types of room-mounted, object-mounted and body-mounted sensors. Context Aware Sensors (CAS), for example, are triggered depending on contextual cues, such as when a person gets close to their local store, which can be determined by using a Global Positioning System (GPS) (ibid.). Remotely triggered methods that react to other environmental conditions remove the burden of self-reporting from the participant, and offer the opportunity to undertake longitudinal studies of use in natural settings. Intille et al. (2003) acknowledge the data collected from such automated tools is only significant when contextual information about user activities is also available, and like all mediated data collection methods, benefits come from use in combination with other methods.

Simulations and Enactments

Rather than focusing on methods for collecting data, Simulations and Enactments rely on participants acting out scenarios, using role-play or imagination, in order to make available information about device use that may not be otherwise accessible or even exist. These approaches make available information about potential or future use situations and allow prototypes to be tested and reflected upon through experiential means. For example, simulating physical movement while testing prototypes in a lab (Beck et al., 2003), expanding traditional lab usability testing methods into the wild (Goodman, Brewster and Gray, 2004), conducting mobile heuristic walkthroughs (Vetere, Howard, Pedell and Balbo, 2003), performing scenarios with a mobile prototype in the context of use (Iacucci, Kuutti and Ranta, 2000), or storytelling to explore product concepts (Still,

Isomursu, Isomursu and Koskinen 2002). Enactments are particularly helpful for researching future technologies where an actual use context does not yet exist, while simulations provide data about use where natural settings cannot be accessed or controlled sufficiently for the purposes of observation and evaluation. Both simulations and enactments rely on a form of pretending, role-playing, body storming or imagination, as researchers and participants simulate or act out a set of tasks, or a particular use scenario.

Simulations

Simulations rely on predefined tasks and generally use quantitative analytic methods including measuring aspects such as timing, error rates and workload. Technology use is contingent on the variables of any given situation and traditional lab based user testing is criticised for isolating technology from the context in which it will be used. This means that data from lab testing does not necessarily translate well outside the lab context (Beck et al., 2003; Intille et al., 2003; Kjeldskov et al., 2005). But because lab testing enables the controlled collection of comparable data, researchers have expended considerable effort to develop ways of making lab testing more relevant and viable for the evaluation of mobile technologies (Pirhonen et al., 2002; Kjeldskov and Stage, 2004; Kjeldskov, Skov et al., 2004; Po et al., 2004). Simulations are also being employed by researchers to avoid the prohibitive costs, both financial and of time, of conducting field studies (Kjeldskov, Skov et al., 2004; Po et al., 2004).

The common factor in simulations is the use of techniques to “reflect or recreate a mobile use situation” (Beck et al. 2003, p 107). Simulations range in their level of sophistication, which is measured by the extent to which the environmental and ergonomic factors of the actual use context are recreated. For example, in conventional laboratory based testing users are seated at a desktop computer. In Baber and Westmancott’s (2004) trial of a multiplayer game, participants were asked to get up and move around while they used the device. Props, such as treadmills, simulate aspects of mobile use related to physical movement and ergonomics (Pirhonen et al., 2002; Beck et al., 2003; Kjeldskov and Stage, 2004). Goodman et al. (2004) extended typical lab usability measures into the street to measure how walking increased participant workload when using mobile devices. Taking the life size experiments outside the lab did result in a reduction in control to some degree, however the advantages were found in the relative realism of the data (Brewster, 2002; Östergren, 2003). Researchers can measure ways in which the mobility of participants and the environmental variables that result from that mobility affect device use, for example, navigating a device whilst walking (Brewster, 2002; Lumsden and Brewster, 2003; MacKay et al., 2005).

Simulations enable the controlled capture of comparable and measurable data that is sensitive in varying degrees to aspects of use in a natural setting. Access to data is more feasible, established mechanisms such as observation and video recording can be used, and quantifiable data can be produced and compared. Similarly simulation techniques and experiments may elucidate factors of ergonomics and device input while mobile. An example of a simulation on a much larger scale is the sophisticated e-Home simulation investigated by Koskela, Väänänen-Vainio-Mattila and Lehti (2004) with characteristics of both field and lab experiments. Two participants lived in a real/simulated home for six months in order to test the usability and usefulness of a mobile phone as a remote control to their smart home. However the key limitation of simulations is that “social context” is missing from most simulation experiments (Beck et al., 2003). While the study by Koskela et al. (2004) provides rich data on the usability and the potential usefulness of such a device, most simulations are still unable to account for many aspects of actual use situations beyond superficial ergonomics.

In a comparison between a life size lab simulation and field trials, Kjeldskov, Skov et al. (2004) identified more usability problems in the lab simulation. However, they also describe how participants behaved differently performing the simulation, compared to actually using the device in the field. For example, in the field trial the participants (nurses) were concerned about the reliability of the system but did not express similar concerns in the lab simulation. Similarly, while participants experimented with using a pen input device in the lab, participants did not use the pen at all in the field. Kjeldskov, Skov et al. concluded that there is little value in performing field trials. In contrast, we suggest that these two examples indicate that people act and feel differently toward a system in a simulation than they do in real use situations. In particular, simulations can be limited by their emphasis on participant/device interaction, at the expense of broader contextual considerations. This means that safe and reliable transferability of findings from simulations to use in natural settings cannot necessarily be relied upon.

Enactments

Simulations are experiments designed to isolate, compare and capture data about variables of use under certain circumstances. Enactments on the other hand tend to be more qualitative in their approach. Researchers facilitate, rather than drive, the process. Enactments use tools such as role-play, imagination and enacted scenarios to make available information about existing user experiences of mobile technologies and the ways in which mobile devices and applications might fit into future use practices. Enactments often make such information available by playing out scenarios about potential devices in the context in which they might be used (Iacucci et al., 2000; Messeter et al., 2004). Iacucci et al. (2000) developed Situated and Participative Enactment of Scenarios (SPES) for this purpose. In SPES researchers observe participants in their daily activities as they improvise possible scenarios with a mock-up of a potential mobile device. These scenarios, which are recorded and fed into the design process, are valuable because they have been created in collaboration with the user and are subject to the variables of the context in which they will be used (ibid.).

We identify storytelling as another form of enactments, in that it relies upon the imagination of participants and is used as a way of making available data about use when there is no existing use context and conventional methods are not appropriate. Still et al. (2002) were working with teenagers to identify possible devices to support an existing online community. They found that teenagers did not respond well in interview situations and little useful data about lifestyles and potential use was revealed. Instead they asked their participants to create stories about a potential device and how they might use it in their daily activities. This approach provided successful methods for discovering potential use contexts and functionalities for a user group that is both difficult to access while, at the same time, a major user of mobile technologies.

Simulations and enactments involve participants acting out tasks, or imagining how devices might be part of their daily activities. They reveal quite different data to that of other conventional methods such as observation, interviews and focus groups. The understanding about use is experiential and based on participation, or a “way of playing with data in embodied ways” (Oulasvirta, 2004, p. 251). In other words, enactments create a shared embodied experience between the researcher and the participant and enhance the researchers knowledge of the environment for which they are designing. However because enactments are not constrained to controlled experimental environments like simulations, they still encounter the limitations typically experienced with direct observation methods. The necessary presence of the researcher in both simulations and enactments restricts their length and viability for use in diverse or multiple locations. The result can be small data samples or short one off testing (Barkhuus and Dey, 2003; Davies et al., 2005; Cheverst et al., 2000).

Other challenges included how to record or capture the scenarios that are being enacted in the field without the researcher impacting excessively on the context of use (Iacucci and Kuutti, 2002). Barkhuus and Dey (2003), for example, addressed this by asking participants to use self-reporting diaries to capture their imaginary use of a mobile device. Participants, involved in a study investigating preferences for context aware interactivity, kept a mobile device with them for five days, imagining that certain applications were available on their mobile phones and recording when they might have used it and why. Using a range of methods to capture different kinds of mobile data can overcome a number of access challenges and enable a comprehensive approach to capturing data about mobile technology use.

Combinations

Combinations of conventional and established methods such as interviews, focus groups and questionnaires have been employed by researchers to collect data on existing user practices, opinions, needs, experiences and requirements, to elaborate on findings collected from direct and mediated observation and self-reporting, and to triangulate data. Although combining methods is not new or particular to mobile research, combinations of the above approaches, as well as combinations including established techniques are particularly suited to mobile studies because of the complexities of accessing and collecting data about use in this domain. Different methods allow researchers to access different data, some rapidly, some in depth and some in real-time. For example, in a study of teenage mobile phone use, Carroll, Howard, Vetere, Peck and Murphy (2002) used a range of existing methods including questionnaires, diaries, focus groups and direct observation. Each of these methods gives access to different types of information about users' experience. Focus groups, bringing together small groups of people to talk to each other, draw out different types of information than when participants speak directly to researchers, such as in interviews. In contrast, direct observation involves researchers being present during and studying, people's everyday practices and activities. Carroll et al. (2002) consider the success of their research to stem from this combination of existing methods; focus groups that provide concentrated interaction with the subjects of the research and direct observation that provides naturalness of setting and reliability of findings. In order to measure usefulness, however, or understand how people will appropriate technologies however, studies must take place over time. Modes of mediated data collection for example, offer the potential for longitudinal studies and for this reason combinations of methods are advocated.

Adaptations on traditional ethnographic methods are also being explored for the purpose of negotiating access to personal and private information. For example, the 'Bag Studies' by Robertson et al. (2005) and taking photos of backpacker notice boards by Axup and Viller (2005). These methods expand and extend traditional ethnographic methods to make information about mobile technology use known by analysing traces of mobility and the artefacts that make such actions possible. We anticipate future research that explores how various combinations of emerging and conventional methods can specifically enable new knowledge about the use of mobile technologies.

DISCUSSION

In this paper we have documented how emerging Mobile HCI methods are making available data about user experience and enabling this data to be collected in different ways. Mediated data collection includes a range of approaches for remotely collecting various types of data by relying on the participant or the mobile technologies themselves. Simulations enable the capture of data about device input, ergonomics and the impact of using a device while mobile. Enactments allow

researchers to explore why we carry these mobile devices with us and what these devices give us the potential to do. Combinations of these and conventional methods allow in-depth and complementary data to be collected.

The use of mobile devices is personal, opportunistic, and dependent on contingencies and occurs over a range of times, ways and places. Knowing when and how to capture actual 'use' instances can be difficult and so is accessing information about how the potential for use affects peoples' behaviour and choices. Axup and Viller (2005) state, "choosing methods from a wide variety of options and then adapting them to fit the situation should be a standard activity" (p 4). Indeed, we found an experimental approach to choosing methods was common across much of the research we reviewed, particularly in relation to field methods. Furthermore, researchers wanting to capture data about and within realistic use situations have also adopted a similar experimental approach to recruiting participants.

Recruitment

Recruitment has been found to be problematic particularly when this might be occurring on location (Axup et al., 2005; Benford et al., 2004; Bornträger et al., 2003; Cheverst et al., 2000; Isomursu et al., 2004) or when researchers are negotiating access to sensitive or personal realms or content (Demumieux and Losquin, 2005; Grinter and Eldridge, 2001; Lamming and Bohm, 2003; Still et al., 2002). For example, Cheverst et al. (2000) were concerned about disrupting the normal activities of the tourists they recruited to field test a mobile guide. Isomursu et al. (2004) noted that recruiting participants to their Experience Clip method was more successful than conventional techniques because participants found the method fun and appealing; the autonomy of participants was retained and the method fitted in with their intended shopping activity.

While technical solutions such as remote devices can overcome some of the physical aspects and challenges of gaining access to data, negotiating access to people's personal spaces is more complex. Sensitive research domains require empathetic methodological approaches and while researchers may prefer conventional methods such as observation and interview, they may not be appropriate. The success of recruiting participants to certain methods may depend on how effectively this is considered. For example, Grinter and Eldridge (2001) found that teenagers were uncomfortable being observed, while Still et al. (2002) found interviewing teenagers to be unsuccessful as an in-depth research tool. Both researchers sought alternative methods to access this important user group. Similarly Axup and Viller (2005) describe in detail their attempts to firstly apply conventional, and then non-conventional, methods to mobile use situations, coming up against challenges posed by the very mobility of their backpacker subjects and their boundaries of personal privacy. In addition, the increasing use of non-conventional methods that explore the boundaries of the personal and the private is resulting in the need to reconsider the associated ethical issues. Ethical implications are being raised both by the nature of working in such a domain and by the new tools we are developing to do so.

Ethics and Privacy

Physical and conceptual boundaries are being crossed and renegotiated in the effort to study, observe and understand relationships and actions that occur close to our bodies and within sensitive contexts. Explorations of mobile technology use by researchers are revealing the need to rethink the classic questions of the role of the researcher and the agency of the participant. These are important questions that influence the actions and perspectives that different methodological approaches can, or cannot support, and in turn the types of data that they make available. In both Enactments, and the

Do It approaches of Mediated Data Collection for example, the agency of the participant is a valuable component of the research. A relationship between participant and researcher is intentionally fostered and the data collected reflects the perspective of those for whom the mobile technologies are designed.

Modes of digital data collection, successful because of their adaptation of discrete mobile digital tools to support remote reporting, also have implications that require further consideration. For example, the social, ethical and possibly legal implications of asking participants to go out and use such devices to record data about their lives. Hulkko et al. (2004) discovered that despite the simplicity of participants using phone cameras to document their actions, asking them to do so while shopping was quite impractical; most shops were unwilling to allow people to take such visual documentation. Similarly, those using such methods must negotiate the responsibilities of participants capturing data, particularly those that might include photos or video, of in-direct or involuntary participants who are not informed or aware of the study. These questions only increase in significance as the debate in mainstream media over inappropriate use of mobile phone cameras in public places grows (e.g. Lawlink, 2006; O2, 2006; BBC, 2006). Our responsibility as researchers to indirect participants is little discussed in current literature and remains unclear.

Inadvertent data collection is further problematised by the digital nature of these mobile devices. Meta data, as well as being a tool that assists auto sorting and filtering of data, can automatically include information and details about which the participants and those in their immediate surroundings might be unaware. While collecting information, such as cell location and the presence of other Bluetooth devices, might be the purpose of using such a data collection model, full disclosure about exactly what type of data is being collected is required. A similar responsibility exists for negotiating ways in which participants have control over, or access to editing data that is automatically collected. As mentioned in the Mediated Data Collection Use It Section of this paper, while participants initially give permission for data to be recorded they may later choose to exempt certain data from the study. Clarifying any such concerns about the collection or storage of any such automatically collected data is an issue for both the researcher and participant (Demumieux and Losquin, 2005; Lamming and Bohm, 2003).

The confidentiality of data collected and displayed online is another issue confronting those using such applications and the responsibilities for data storage, access, future use and ownership take researchers through an often unanticipated maze of competing interests from private and public domains that existing research ethics committees are ill-equipped to manage. As the presence of mobile devices continues to grow and new digital methods expand they will require more of our attention as researchers.

CONCLUSION

The mobile HCI community is steadily building research methods for understanding mobile technology use that rely on a range of different methods combined with valuable new opportunities created by the mobile technologies themselves. In addition, a significant research direction is emerging in the area of the automatic extraction of complex data about technology use through mediated data collection methods.

Although researchers (e.g. Beck et al., 2003) report finding very little variety in the use of new techniques for Mobile HCI, we have found this not to be the case. The possibilities for researchers to understand mobile technology use in real settings are richer than might first appear from Kjeldskov

and Graham's (2003) broad review of mobile research methods. As self-reporting techniques become more sophisticated, people using mobile technologies are increasingly being asked to also act as the observers of their own use. Interestingly, neither of the reviews by Kjeldskov and Graham (2003) or Kjeldskov and Stage (2004) refer to forms of self reporting, which our survey has found to be a significant tool for studies of mobile use. It may be that this significance was not yet clear when these earlier studies were written.

In order to understand mobile technology use, we must also ask how mobile devices shape and reshape the body and its relationship to the environment (Viseu, 2003). In future research we hope to further examine the use of these different approaches and the physical, personal and ethical issues of accessing and collecting data for mobile technology use. Research that moves beyond measuring user device actions or input while moving to a deeper understanding of the personal capacity for use afforded by mobility leads to a complex, largely intangible and difficult research domain.

It is possible that simplistic conceptualisations of mobility may have contributed to an emphasis on mobile HCI research methods that conceive of mobility as an ergonomic or physical characteristic, rather than, as in Merleau-Ponty's (1962) philosophy for example, a fundamental constituent of human behaviour. There is little research to date that reflects upon the existing assumptions about mobility that form the basis from which much of the literature and resulting studies depart. Conceptualisations of mobility that consider the implications of mobile devices as they integrate into our lives and enable different connections, communication and behaviours will enable us to increase our understandings of this particularly challenging area. At the same time they will assist in the continued development of appropriate and flexible research methods and data collection tools.

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Editorial note: the numbering of references is used only for convenience in presenting Table 2 above.

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