

Unremarkable Computing: Routines and the Design of ‘Invisible in Use’

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Abstract. In this paper, we aim to move the Ubiquitous Computing agenda forward by focusing on one of its earliest, but most difficult, ambitions - making technology “invisible in use”. We draw on field studies of domestic life as this domain is becoming increasingly important for new technologies and challenges many of the assumptions we take for granted in the design of technologies for the workplace. In particular, we analyse some examples of domestic routines and identify a number of insights into what it means for the features of activities to be “unremarkable”. We conclude by using these insights to critique some of the current emphases in ubiquitous computing research, and suggest how we might better understand what will be required to develop technologies that really are “invisible in use”.

Keywords. Ubiquitous computing; calm computing; ambient intelligence; intimate computing; ethnography; ethnomethodology; field studies; domestic environments; technology for the home; routines; context.

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Computing, the office has been the default domain:

Inspired by the social scientists, philosophers, and anthropologists at PARC, we have been trying to take a radical look at what computing and networking ought to be like. We believe that people live through their practices and tacit knowledge so that the most powerful things are those that are effectively invisible in use. This is a challenge that affects all of computer science. Our preliminary approach: Activate the world. Provide hundreds of wireless computing devices per person per office ... (Weiser 1998)

In our current research we have been considering the notion of Ubiquitous Computing in the context of another domain – the home. This has been motivated by changes in work practices and technology that have led to a significant growth in the numbers of people working from home, throwing into sharp contrast the office/home boundary and highlighting the different design approaches that have been traditionally adopted within these two domains. While much of the vocabulary of the office revolves around tasks, processes, productivity and functionality, the language of the home is often oriented towards lifestyle, aspirations, emotions aesthetics, form and so forth. Yet, as Ubiquitous Computing takes hold, we can expect that computing will increasingly expand from the work domain and become embedded within home appliances and domestic environments. Consequently these two technology and design traditions are on a potentially fascinating collision course. We are also motivated by a belief that the radical differences between the home and the office may cause us to re-evaluate many of the assumptions buried within prevalent views of Ubiquitous Computing. Alternative domains have a habit of challenging consensus and questioning engrained perspectives.

Despite our overall goal of understanding how ubiquitous computing might arrive and make its place in domestic everyday life, our first concern in examining home environments is ‘to let them speak for themselves’. Our approach has been one of ethnomethodologically-informed ethnography through which we seek to understand, pre-theoretically, the concrete lived details of phenomena and to bring out the *ethno-methods* (Garfinkel 1967) and tacit resources whereby things get to look the way they do.

The glue of domestic life

As we set about looking at the everyday phenomena of life and work within the home it became evident to us that one of the most significant and ubiquitous ways in which this is managed is through routines. In fact the role of domestic routines was such that in home settings where work was also done we found that work routines were typically made subservient to domestic routines with work being seen as a thing that (within certain confines) can be done anytime within the day whilst breakfast has to be *now*, the children have to get to school *now* and so on. There is a sense in which routines are the very glue of everyday life, encompassing innumerable things we take for granted such that each new enterprise can be undertaken unhesitatingly. This is especially pertinent in the home where the highly disparate priorities of different family members have to be realised without the commonality of an orientation to some shared work objective to bind them together. Routines help provide the grounds whereby the business of home life gets done so that people can get out the door, feed themselves, put the children to bed etc. without having to eternally take pause and invent it anew or open up its every facet for inspection, comment, challenge or the generation of accounts.

PREVIOUS WORK ON ROUTINES

Despite the significance of routines in domestic life there is, to date, little empirical understanding of their fundamental nature and no way has yet been found for such an understanding to directly impact the actual design of domestic technologies. In contrast the study of routines in the office environment has had a direct impact upon computer science in fields such as CSCW. The significance of the notion of ‘routines’ came to the fore in the late 1970s and early 1980s when technology developers began to explore ideas of ‘office automation’. It was the field studies of researchers like Wynn (1979) and Suchman (1987) which first demonstrated the rich and complex nature of allegedly repetitive activities and the

skilled and cooperative decision-making and negotiation necessary to ‘get the work done’.¹ Suchman in particular was able to suggest a radically different sense to ‘routine’ and illustrate the importance of an ethnographic orientation to the status of procedural plans, seeing them as accomplished products rather than as structures which stand behind the work. Embedding representations of routines within systems (such as workflow tools) was seen to change the status of those representations from being a resource for situated action to becoming something to be enacted programmatically. A focus upon supporting work with resources rather than automating it has now become a distinctive characteristic of Computer Science in CSCW, influenced by this understanding of the status of representations of routine processes and emphasizing ‘routineness’ as an accomplishment produced through the practised exercise of complex skills.

A FRESH LOOK IN THE HOME

We would certainly not wish to understate the significance of the above body of research. Indeed, the work of Suchman was motivated by the same core interest and approach as our own. However, this is now a well-worn path, where the primary focus has remained upon *work* practices and the *office*. So, rather than replay here the lessons of CSCW by applying them once more to the field of Ubiquitous Computing, we intend to put them aside for the time being and take a fresh look at routines and their significance in a new domain - the home. Domestic routines cover a wide range of phenomena with many research implications. Our aim in this paper is a modest one: we seek only to begin to identify, through empirical materials, some of the features that might serve to give things a *routine character* in the home.

Instances of routines

1. PERCEPTUAL VISIBILITY AND PRACTICAL INVISIBILITY: THE ALARM CLOCK

Our first instance of interest is an extract from a study of a freelance translator working at home. The translator in question, Lucie,² lived in a small 3-bedroomed house with her 2

¹ See early Office Automation research in the late 1970s and early 1980s; e.g. Zisman (1977) and Ellis (1980)

² Proper nouns have been changed throughout to preserve anonymity.

children, a boy aged 12 and a girl aged 10. The previous year she had moved from doing translation work in an agency to 'going it alone' at home and had converted one corner of her living room into an office. Translation work turns chiefly upon the physical number of words one can translate in any one session, so she frequently started work early in the morning before her children had got up in order to get as much as she could done without interruption. This instance is drawn from observations of one such early morning session. Lucie has been sat at her desk, translating from English into French a text describing a new dieting aid, since about 6:00 a.m.

Instance 1:

Lucie flicks through some printed sheets on her desk and comments on how the table of contents doesn't match the text. She returns to the electronic document and continues to translate the next title, saying out loud a segment in square brackets. It is 7:00 a.m. and an alarm goes off upstairs which she totally ignores, continuing to key in as before. When she has completed that section of text she switches her monitor off and says 'it's been an hour'. She pushes in the leaf to her desk, stretches, then leans on the ledge under her monitor resting on her elbows, her hands to her cheeks, drinking coffee. Once she has finished her coffee she goes into the hall to call upstairs to the children: « Bonjour mon gros doudou, Bonjour mon lapin... »



Figure 1. Not noticing the alarm going off?

One feature we would particularly like to draw attention to here is the way she shows no response to the alarm going off upstairs at 7 o'clock, despite going to the foot of the stairs to

call up to the children a short while later. To the ethnographer the alarm going off is a notable enough event for it to be recorded in the fieldnotes. Yet, for Lucie it passes by without remark.

Yet, how would it have been had she paused to take note of it, perhaps saying something like ‘Oh, is it that time already?’, or even ‘whatever is that?’. In the first of these cases she would have preserved the actual going off of the alarm’s ordinariness by not seeking to account for why that had happened. Rather the event would have become a resource for commenting upon something distinct about the current situation. In the second of these cases an explicit drawing attention to the alarm by saying ‘whatever is that?’ would have marked out to anyone who was there to witness it the ‘unusualness’ of the occurrence, with an ‘ordinary’ next step being to seek out some account, for instance ‘the alarm has been set wrong somehow’. However, in Lucie’s very *disattending* to the alarm she displays her orientation to it as something wholly unremarkable. And by *visibly* failing to attend she provides for the sense of the going off of the alarm upstairs at seven o’clock in the morning as being a matter of routine, for who would comment upon a feature of their routine as though it were somehow special? So here we have some initial, orderly features of what routines might consist in:

- Routines are i) unremarkable in their realization; ii) can be disattended to, which renders them visibly unremarkable; and iii) For those who enact a routine, to remark upon the routine is itself something that is remarkable and accountable.

However, although the alarm going off is visibly unremarkable, that is not to say it is a thing without import. For a start it is a thing of import for her children. Its very mutual availability to Lucie and themselves makes ignoring it highly accountable. Consequently, it is a resource that can serve to initiate other features of the everyday morning routine, such as getting out of bed, going to the bathroom, getting dressed etc. So, despite having rendered the alarm unremarkable by ignoring it, were it to be ignored by *her children* Lucie could unproblematically hold them accountable. That makes it a resource for her as well. This is made visible by her subsequent movement to the foot of the stairs to call up to them. Similarly, though aspects of routines may never be directly remarked upon, a failure to attend to their implicativeness is accountable in the very terms of what is usually unremarked, e.g.

‘didn’t you hear the alarm going off?’ So, to answer the question under the above photograph, it is not the case that she is not noticing the alarm going off. Rather she is not *displaying* that she has noticed because to display that notice would be to make her accountable for her interest in its significance. Finally, one can imagine instances where she might display some interest in the alarm *not* going off, perhaps by noticing the time and realising the alarm has failed. This displays an orientation to the alarm as something ‘nodal’ upon which many other things may turn. So her disattention to its going off is certainly not dismissal. Furthermore, should it fail to go off that failure can itself be quite specifically attended to.

Alarms then can be perceptually visible yet practically invisible in use, as part of what has been made routine. What matters about the alarm is, in this case, not so much its perceptual character as its significance, a significance that can be made explicit should the alarm ever fail. So here we have some more orderly aspects of routines:

- iv) The features of routines serve as resources for the mutual co-ordination of unremarkable doings in that they are: a) mutually available resources, and b) mutually accountable resources to those who enact them; and v) Within many routines there are nodal occurrences that are implicative for everything else that follows;
- vi) Failure to enact a routine is held specifically accountable to the routine that failed, and vii) The failure of a routine is specifically remarkable;
- viii) Disattending to a routine is in no way equivalent to not noticing the routine; so ix) Artefacts implicated in routines can be perceptually available yet practically invisible.

The above instance begins to demonstrate how routines can serve as mutually available, mutually accountable resources for articulating particular courses of action, like getting up. However, it is also the case that routines can serve as that kind of resource for articulating courses of action *between* households. In the next example we see how ‘knowing the routine’ enables members of two separate households to accomplish a particularly fine-tuned course of action.

2. DONE IN THE DOING: THE KNOCK ON THE DOOR

The following abbreviated accounts are descriptions of two distinct but related instances drawn from observations of the domestic round of a family with two children, one aged 12 and

the other aged 9, collected on different days. Both of the instances occur at the time of the mother, Christine's, departure to pick up her youngest daughter, Susie, from school.

Instance 2a:

Christine has been sitting at the end of the garden in the sunshine drinking a cup of tea. It is 3:00 p.m. and she is heading back to the house to get ready to go and get Susie from school. She goes into the kitchen through the back door, shuts and locks it and closes the kitchen window. Then she puts away some shopping that she has left out before picking up her mobile phone and going through into the hall. She puts a few items on the stairs and goes into the living room. There is a knock at the door. She goes into the hall and half opens the door and, without looking to see who is at the door or giving any verbal response, goes back into the living room to finish what she is doing. Then she goes out onto the street, shutting the door behind her. Her next-door neighbour, Louise (who is also her sister-in-law), is walking slowly up the street and looks to Christine as she comes out. Christine heads over to Louise, commenting on the heat, and they walk up the road together towards the school.

Instance 2b:

It is a couple of minutes past 3:00 p.m. Christine has just gone into the house from the back garden and has been going round closing doors and windows. A moment later the door to both her house and Louise's house next-door, open and they come out down their respective paths. They look at one another and Christine says "That was good timing". Louise pauses at the end of her path and when Christine reaches her they walk off up the road together in the direction of the school.



Figure 2. "That was good timing"

As some additional background it is worth noting that Christine and Louise have never discussed this arrangement, it having 'just evolved'. Finding they were leaving at the same time, they had started to walk to the school together, with whoever comes out first knocking

on the other's door before heading off to the school. Neither of them waits if the other one doesn't come out.

Knocking as a 'message'

We might first of all wonder about what is accomplished through this knock on the door. Actions such as 'knocking on a door' can achieve various things beyond just making a sound on a door: they can be a statement that 'I'm here' or a means to 'check for absence prior to entry' or a confirmation of the ownership of a space and the rights of access to it. Clearly a knock such as this could be a 'summons'. However an ordinary thing about a summons is that the summoner waits for the summoned to answer, yet that is clearly not what is being oriented to here. In instance 2a, Christine could have answered the door as soon as Louise knocked on it but instead a thing happens that would be unusual in most other circumstances: Louise walks away without waiting for Christine to answer. This is not, however, some form of peculiar game. In fact, Christine in no way holds Louise accountable for that behaviour. The knock, then, is oriented to as not so much a summons as a *message*, the import of which is only locally intelligible where, for each of the mothers involved, it tells them that the other mother is about to walk to the school.

Opening the door as a 'message'

Another otherwise strange feature of instance 2a is the way Christine only half opens her front door and immediately returns to what she is doing without speaking to the person knocking at the door. One would typically expect that either a caller would be greeted or that a half opening of the door followed by walking away would be highly accountable, for instance by saying "sorry, I was just in the middle of something". Christine however clearly has a solid *expectation of the implicativeness* of this knock such that she can disregard the possibility that her actions might be held accountable. In order to understand the import of this half opening of the door it is necessary to recall the logic of this arrangement whereby, should the knocking individual get no response, they can treat that as licence to just walk off to the school on their own. So Christine's half-opening of the door is just enough to suffice as an acknowledgement

whilst she is involved in doing something else. The opening of the door, then, also serves as a message, whereby an announcement of imminent departure can be acknowledged.

Context specific meanings

We now want to move on to considering how it would have been if the knock on the door had taken place at some other time of day, somewhere else, or at 3:00 p.m. on a Saturday. Clearly the phenomenon here involves preparations to collect a child from school and only works and has intelligibility at a very specific time of day, and only on certain days for certain weeks of the year. Both Christine and Louise are able to mutually orient to that highly specific intelligibility in such a way as to enable the co-ordination of one specific commonality of routines between two families. The particulars of *how* it is realised serve as a resource for achieving that sense of having a shared routine that can be effectively co-ordinated. It turns upon neither of them specifically opening up the operation of it for comment or problematising its unique features (which, in relation to all the many things that knocking on a door and opening up a door might amount to, are quite distinctive). In instance 2b for example what is remarked upon is not the practice itself but rather the perfection of this particular realisation. The beauty of instance 2b is that, in that one moment where they walk out of the door together, the very need for there to be the originally observed phenomenon, a knock on the door, simply fades away and reveals that this is never simply about knocking on a door at all. That is only ever a resource to bring about what they are really after, which is to walk to the school together, rather than separately and alone. It provides for all of those occasions when they fail to walk out of their front doors at the same time as one another. But when they do, to still knock on one another's doors would be patently absurd.

The features of the realisation of this particular routine turn upon the mutual intelligibility of certain highly specific courses of action that in just about any other set of circumstances might be meaningful in other ways. They provide for a highly nuanced adaptation of wholly mundane physical and interactional resources such as knocks on doors, and openings of doors through the very unremarkable, dis-accountable, yet consistent regularity of their realization. They provide for this in such a way that some, at first sight strange, happenings at 3 o'clock on

a school day can add up to something meaningful and evidently unremarkable for two mothers from different houses who want to walk together to school. So, to summarise what we have discovered here:

- x) Specific meanings can accrue to certain activities such that they can serve to facilitate the coordination of certain routines which are only locally intelligible; and xi) these locally intelligible resources can also be used to coordinate routines across households.

In our final instance we seek to both delineate what we have said about what provides for some course of action having a *routine character*, but also to begin to demonstrate how ‘knowing other people’s routines’ can itself be a powerful resource for articulating and gearing together highly distinct orientations and goals, where it may be that one of the interactants is *never normally party to that routine at all*.

3. KNOWLEDGE OF OTHERS’ ROUTINES: GOING TO THE COFFEE SHOP

The instance is gleaned from an ethnographic study of the work of a freelance website designer and graphic artist, Michael Jones, who works at home. Michael likes to focus his business upon the local community and engages with many of his clients face to face at a local coffee shop. This particular sequence of events was prompted by Michael working through a To Do list he keeps on his desktop in MS Word, which he checks through at the beginning of each working day:

Instance 3:

Michael is greying out things he’s done on his To Do list – He says about needing to do something about ‘John’s’ opening times – [John is the proprietor of a local Farm Produce Shop] – He knows John wants them changed on his poster but doesn’t recall for sure what to. Michael goes to a folder on his PC titled ‘Posters’ and clicks on a document called Farm Shop which opens in Illustrator. Leaving the poster open he goes to phone John. However, John doesn’t answer. He notes that the time is about a quarter to ten – He says he thinks he will go to the coffee shop [a small coffee house just around the corner] where he thinks he’ll catch John because John usually goes in there for a coffee before opening up the Farm Shop at ten o’clock - When he gets to the

coffee shop he sees John waiting at the counter – He goes up to talk to him and says about the poster, checking what times John wants to go on it. While Michael queues they talk about John’s website and some advertising he wants done for some chocolate products he’s going to be selling. Just before ten o’clock John goes off to open the Farm Shop and Michael says he’ll pop in to see him later and talk about things in more detail.



Figure 3. Meeting at the coffee shop

Now, so far we have looked at examples of routines that are oriented to as resources for doings within a particular household, and across two households with certain common interests. However, this instance is quite distinct in a number of ways. There is no matter of course requirement upon Michael that he should specifically co-ordinate his routine with John’s and he has no particular accountability placed upon him that he should attend to that routine at all. In direct contradistinction to our previous observations Michael quite specifically *marks out* what he knows of John’s routine for comment – he knows that John goes to the coffee shop every morning before he goes to open up the shop. In this way, John’s activities have been made a matter of note for Michael in a way that John himself might not ordinarily take note of them. John would be unlikely to mention to, say, his partner before leaving the house that he was going to the coffee shop if that was a thing he did every day because the mentioning would invite that it be seen as something out of the ordinary and specifically *significant*. John

might make mention of that as a thing he did by habit to facilitate someone like a visitor finding him, but such a mentioning is a quite separate occasion to actually going to the coffee shop as a matter of routine.

All of these observations are not independent of one another but are, in fact, quite tightly related. It is exactly because Michael is not a member of the cohort governed by John's routine that it can be, for him, a matter of comment. As he is not accountable to it, so he is also not accountable for having made something notable and significant out of what, for members of John's family, is necessarily taken for granted. Furthermore, Michael is not engaged in a routine activity himself. His doings are notably occasioned: he needs to talk to John about the poster now because he wants to work on it, but John isn't there when he tries to phone him. As his actions are occasioned, so his motivations in those actions are open to quite explicit justification. So here we have someone not pursuing their own routine but using what they have explicitly noted about someone else's routine as a resource to bring off a particular course of action. This use of other people's routines as a resource for tailoring specific actions has been noted in a number of other studies, including studies of domestic telephone use where some pretty fine-tuned judgments can get made about 'when it's a good time to phone' (Lacohée and Anderson 2001).

What we are not saying, however, is that members are somehow oblivious to their routines just because they never remark upon them in the actual course of doing them. On the contrary, one can perfectly well bring forth an account of routines and justify them in the context of other occasioned activities, like being interviewed. In these cases, though, the mention of details of routines is specifically occasioned, and picking them out imbues these things with a certain significance. This is different from the actual realisation of routines where to give them some marked significance is wholly contrary to just taking them for granted. Indeed things that are taken for granted form the very background against which one might take note of other, distinctively occasioned and therefore notable activities.

So we can note here that there are perfectly accountable circumstances for explicitly remarking upon both one's own and other people's routines, but, importantly, these remarks are situatedly *occasioned*. Furthermore, one of the ways in which people's routines become

discoverable to others is through such *occasioned* circumstances where people explicitly provide details of their routines within accounts. However, in this particular case the availability of John's routine for Michael's own inspection was a matter of his own *noticing*, rather than through any particular account. It was a thing he had discovered through his own recurrent visits to the coffee shop – visits that, whilst not time-specific, were wholly a feature of his own routine. What marks out the above instance as something different is that he then makes use of that discovery in an *occasioned* rather than a *routine* visit to the coffee shop. So, to summarise:

- xii) There are accountably appropriate motives for displaying interest in someone's routines; and xiii) Such interests are specifically occasioned;
- xiv) People can provide accounts of their own routines, but such accounts are occasioned: discovering what is relevant within the routine is bound up with that occasion; xv) Through such occasioned accounts and noticings the routines of others can be discovered and made available for use; xvi) Knowing the routines of others can serve as a resource for a large number of other occasioned activities

Significance for ubiquitous computing

We have then pointed to a number of features of things that have a routine character and the strong sense in which routines are deeply unremarkable. It seems then that, in their own terms, routines are invisible in use for those who are involved in them. Returning then to the agenda set by Mark Weiser and quoted at the beginning of the paper, we wish to consider what it is about the ways in which routines are unremarkably 'just there' that could help us develop Ubiquitous Computing that is invisible in use, that is in its own way unremarkable. The aim then is, again, well articulated by Weiser (1994):

For thirty years most interface design, and most computer design, has been headed down the path of the "dramatic" machine. Its highest ideal is to make a computer so exciting, so wonderful, so interesting, that we never want to be without it. A less-traveled path I call the "invisible"; its highest ideal is to make a computer so imbedded, so fitting, so natural, that we use it without even thinking about it.

Routines have then many of the qualities we may be aiming for in that they are tacit and calm in that they do not draw attention or demand attention except when they need to. They are seen but not noticed. They are themselves used as resources for action and the resources involved in them (doors, alarms, coffee shops and so forth) have been made unremarkable and routine. However, just how to go about making computing “so imbedded, so fitting, so natural” remains, we would suggest, unsolved. In fact a central point of this paper and the one to which we now wish to turn is that many of the ways in which solving this is being approached seem not to match with the features of routines and the use of resources within routines which we have observed.

USE AND INHERENT QUALITIES

Let us take as a first example the sense of computing as something that could ‘disappear’. Here we see an attempt to convey what this might mean from a research project on ambient computing.³



Figure 4. All sorts of computing devices (left) will disappear into the background of our everyday lives (right) Obviously this is an attempt to visually convey what might be meant and we are not unsympathetic to what is being attempted here. However these images can lead one to focus upon the *perceptual* visibility or invisibility of computing. We feel that perceptual invisibility is not necessarily the same as the achievement of invisibility in use. The alarm clock example described in instance 1 very much involves a perceptually demanding device yet one that has

³ Philips Research, <http://www.research.philips.com/generalinfo/special/ambintel/index.html>

been made routine. The alarm has not been made smaller or quieter or some how perceptually ambient but has rather, as a function of use, been made unremarkable. Perceptually the alarm remains an alarm but it is not attended too because its significance has been made unremarkable. Similarly, an alarm not sounding at all could very well be a remarked upon event.

The notion of “invisibility in use” is a difficult idea and the exact implications for the design of technology have not yet been thoroughly explored. However, it is all too easy to understand “invisible in use” as meaning literally (perceptually) invisible: the miniaturisation of computational technology, itself a driver of ubiquitous computing, has already enabled devices to become smaller and perceptually less visible (encountering a 1970s mainframe in your living room would be somewhat different from encountering a PDA.) However, we feel that a different, understanding is required for Ubiquitous Computing, and was, we believe originally envisaged as part of the ubicom program. However the most familiar examples are often misunderstood as pointing to perceptual issues. What we think is important about the well known example of “The Dangling String” (a piece of string connected to a motor that changes speed according to the network traffic (Weiser and Brown 1996)) are not the perceptual psychology issues (“periphery”, “attention”, “attunement”, “peripheral sensory processing” (ibid.)) but the features that enable it to become a resource in action.

Clearly, there *are* perceptual qualities which are critical to creating an “invisible-in-use” phenomenon:

- that the phenomenon can be “disattended to” implies that it must be “endurable” (the string would not work if it were designed as a loud siren of varying pitch)
- that the phenomenon can be attended to implies that it must be “available” within the context of the routine (an alarm is no use unless you can hear it).

Yet the question for us is not what perceptual qualities allow the device to be attended or disattended, but rather how do people embed these perceptual resources into their routines so that they can attend and disattend to them as needed. We feel that this notion of “invisibility in use” is already prefigured in Weiser in his attempt to turn attention away from the search for better ‘inherent qualities’ of computers. What is not sought is a computer that is more intimate

(Weiser 1993) or even more intelligent (Weiser 1994) but rather an altogether *unremarkable computer*: “Whereas the intimate computer does your bidding, the ubiquitous computer leaves you feeling as though you did it yourself. “ (1994a)

Similarly perceptually invisible is not the same as invisible in use. The point is not to adjust the perceptual qualities by, for example, making computers visually disappear, or producing notifications that are perceptually ‘softer’. These do not necessarily make the computer less present. The aim is not for a hidden computer. Indeed a computer that behaved as computers currently do and required the same form of interactions as computers currently do but which could not be seen or heard could be *more* remarkable, *more* present than before. The challenge for design is to go beyond focusing simply upon the perceptual qualities of devices and to make computational resources which can be embedded into routines and can augment action.

AUGMENT THE ACTION

Here then we wish to move onto our second point – that it is actions that we need to augment not artefacts per se. We may sometimes need to augment artefacts in order to augment actions but those artefacts are to be in service of the actions and their augmentation should be motivated by their role in those actions. If we consider for example fieldwork instance 2a, clearly everyday artefacts and actions are being used. The doors are offering hard surfaces which hands can knock on to make sounds, they are offering solid barriers which can be opened to allow entry, closed to prevent it or opened to varying degrees. These are then mundane features of the tangible world that are being manipulated using mundane competencies people have for touching and moving surfaces. However, as we have noted, much of the significance of the use of these doors comes from what is done in the doing of actions with them. The knock on the door is not only the action of lifting ones hand and connecting it to the physical door artefact so as to make a sound that can be heard by those on the other side of the door. It is, in this case, also a means to coordinate actions and to make others aware that you are ready to begin a routine. These are the significances of these actions. Furthermore as we have seen in instance 2b there are other ways of achieving these aims and

occasions where these artefacts need not be used at all and hence the actions are simply not taken.

This suggests to us then that a little caution is required about over hasty moves to augment tangible artefacts that are used in activities. Again we are sympathetic to what is being attempted in the tangible interface paradigm. Firstly when attempting to make computing “so embedded, so fitting, so natural” then augmenting physical artefacts is highly appealing in itself especially if these provide visible interaction mechanisms for perceptually invisible computer hardware. Secondly the tangible interface approach is a perfectly coherent HCI approach. After all, the manipulation of physical objects is (one of) people’s everyday competencies and one that is more generally available than, say, abstract computer commands and software applications. There is a logic behind developing tangible interaction mechanisms just as there is a logic to other interaction paradigms based on everyday competencies: spatially based systems⁴; graphical and visual-symbol based interfaces; and even languages with which to interact with computers (given that learning and using languages is an everyday human competence). These everyday competencies are however deployed *so as to* communicate, organize, coordinate and so forth. Augmenting a door artefact (e.g. to enable remote notifications) can only be a sensible design choice when one understands the significance that this artefact and the associated action of ‘knocking’ has.

In this context the point for us is not that interaction with computation may be mediated through tangible mechanisms (Brave and Dahley 1997) or that it is mediated through the augmentation of everyday tangible objects (such as the Media Cup (Gellersen *et al.* 1999)) or even that it is mediated through natural language, speech or gesture. Rather the point for us is that the computation is in service of actions – everyday actions – which themselves have a significance. The knock on the door is an *action that signifies*. To focus only upon the door artefact is to (literally) take a surface interpretation of what is going on and what people are doing. Augmenting artefacts needs to be in service of the actions done with those artefacts but also in service of what is “done in the doing” of those actions (what is achieved or conveyed

⁴ Such as the early ‘rooms’ interface (Henderson and Card 1986) and later work with virtual environments (Benford *et al.* 2001).

by the doing). Remember that in instance 2b the door is dispensed with completely as an artefact for coordination because that has already been done in other ways. One would not want to require someone to knock on a door to announce their departure to some one who was already standing next to them ready to depart. The design goal then is to augment the resources, tangible or otherwise, which are available to the action and to what is done in the doing of that action. Put simply, we need to embed computation within life not just in cups.

RIDING EXTRA SEMANTICS ON THE BACK OF TANGIBLE ARTEFACTS

A related error is, we believe, to assume that embedding computation within an existing tangible artefact is guaranteed to merely ‘augment’ that artefact in ‘natural’ and ‘intuitive’ ways rather than to fundamentally change (if not confuse) the semantics of exactly what that artefact is. We have suggested then that a fundamental issue for us in things that are ‘invisible in use’ is not the physical nature or particular perceptual qualities of these things but rather the significance which accrues to them within a particular course of action. The issue for us is then one of what one might call “user semantics” and here we target an area that is between and deliberately separate from system semantics (what entities know about themselves and others) and interaction mechanisms (how users interact with the system). User semantics is rather what the user knows about the world and how they understand, for example, what is available, what can be combined, what is configured already and so on. That is, while we are interested in and recognize the challenges both of novel interaction paradigms and of system-level problems in Ubiquitous Computing, we also see a middle area which can tend to be slipped over and which regards user semantics. Indeed issues of new user-level semantics can be mistakenly conflated with tangible computing interaction mechanisms.

Not explicitly recognizing this level can make it harder to conceive and evaluate designs in which changes to the semantics of objects are being introduced. For example, one might, as a design choice, choose to embed within a door a mechanism such that whenever it was knocked upon, it displayed a personalised newspaper, or debited a credit card or changed channels on a television. The point is not just that these may not be desirable additions to the functionality of the door but rather that they would change the semantics of what this door was

– perhaps usefully so and perhaps in ways that could be easily learned but still change nevertheless. Furthermore, we have seen in instances 2a and 2b that *this* knock on *this* door for *these* people at *these* times is not a request to enter, not a warning before entering, not a test to detect for presence but rather an announcement of imminent departure. That is, not only is more done in the doing than just the doing but it is also the case that what is done in the doing is ‘just that’ and not something else. Consequently while some doors and some uses of some doors by some people at some times might lead one to want to, say, augment those doors such that, for example, the doors capture details of all who called by while you were not there or which displayed whether the room behind them was occupied or not, that would not be the kind of augmentation of value for the doors, the actions with the doors and what was done in the doing of those actions with those doors in instance 2a.

The nature of the augmentation is not then simply one of computation. Computation is the mediator but the augmentation is one of the semantics. The assignment of augmentation, the assignment of semantics should then be a matter of careful consideration. That those extra semantics are being embedded in a tangible device is no saviour, it does not in itself mean that the orientation and use of *those* semantics are somehow natural. The existing semantics may be natural or at least known and understood but the assignment of extra semantics cannot be guaranteed to ‘ride on the back of’ the semantics of the initial artefact. This augmentation may then be a matter for careful design reflection and indeed the artefact may have to be redesigned so as to make its new semantics understandable.

SUPPORTING ROUTINES THEMSELVES

As we turn towards augmenting actions and the sense of those actions within sequences of actions, then routines themselves become a topic of interest. Routines are a form of action sequences and, as we have noted, are generally unremarkable and provide the omnipresent glue of domestic life. The question is what will it really mean for Ubiquitous Computing to fit comfortably within routines and avoid losing the unremarkable qualities that make them what they are. We might expect ubiquitous computing components to fit into and augment everyday routines – for example how might a ubiquitous computing environment provide alternative

ways of serving the communication that is taking place around the knock on the door in instance 2. Or to draw on instance 3, what would it mean for Ubiquitous Computing systems themselves to draw upon knowledge of peoples' routines in order to be context-sensitive, to support a calm world of computing, to detect the intention for users, to seamlessly recombine computational resources, to perform low level connections and transformations and to just 'do the right thing'.

We have seen how in the office environment Office Automation systems did not appreciate the status of representations of routines by embedding them within systems. Similarly the status of user accounts of routines needs careful consideration. In particular we see accounts of routines as occasioned matters and separate from the actual doing of those routines. A consequence of this is that care will be needed to ensure that systems do not transform the unremarked nature of doing routines by marking them out through supporting them. That is the marking out of actions within routines can be the very thing that disrupts the doing of routine sequences of actions. Systems must be designed such that background is not made foreground, the routine is not made episodic, the taken for granted does not become notable, the matter of course does not become a matter of comment.

Is developing Ubiquitous Computing that supports or uses an understanding of routines therefore impossible? We would argue not. We have seen that routines are indeed resources for action and knowledge of others routines can also be resources for action and interaction. Routines are knowable, teachable and breachable. To some extent the same may be true for systems' comprehension of routines. However, we would suggest that attention needs to be paid to the distinction between, on the one hand, routines being visibly unremarkable in their realization and, on the other hand, accounts of routines being occasioned and the accounts of what is relevant within the routine being bound up with that occasion. We believe that there are deep challenges in trying to provide unremarkable computing for unremarkable routines. We are beginning to explore two potential topics within this area.

NODAL POINTS WITHIN ROUTINES

The first is that within many routines there are *nodal* occurrences that are implicative for things that follow (such as the alarm clock or the knocking on the door). These may be, for

example, utterances that open up conversations or close them down, actions that initiate sequences or conclude them. Not only may these points be useful points to detect but they may be points for potential augmentation and points where requiring that they are made more explicit in their marking out is less disruptive than other points. The challenge is to be able to identify such points, to understand the potential for augmentation through ubiquitous technologies and to understand requirements for these technologies so that they can realistically become part of a routine.

THE SYSTEM AS 'PARTICIPANT'

Weiser set himself the challenge of “could I design a radically new kind of computer that could more deeply participate in the world of people?” (Weiser 1995). We should of course not interpret this as a call to develop intelligent agents that are indistinguishable from people in their behaviour – for example, Suchman (1993) has clearly articulated the asymmetry in the sense making abilities of people and computers. Rather the challenge is to work out how the “sense making” that can reasonably be expected from a computational system can be of value in the support of human activities. It is not unreasonable to expect the system to be treated as an active participant in human routines so long as its inherent limitations are clearly understood. For example, how might the system help suggest John’s whereabouts in instance 3?

However, it might be more appropriate to think of the system as more akin an ethnographer than a participant. Participants have an *egocentric* view of other’s routines because knowing another’s routines is a practical matter, it is a resource and only needs to be adequate for the participant’s purposes. It is in this sense specific and partial as the purpose is not a passing abstract and general interest. For a system to “get it right” implies major challenges in access to and use of contextual information that are likely to be beyond what it is reasonable to expect. The accounts of the kind an ethnographer gives are more like the basis that might be appropriate for a system to embody – they are likely to contain a better articulation of the home’s routines than a participant will be able to produce easily, and by so

doing leave the more subtle issues of how this should be used in a particular situation to the human participant.

Conclusion

We have demonstrated how lessons that challenge and can help develop the Ubiquitous Computing agenda in the direction of technologies being ‘invisible in use’ can be drawn from studying the domestic environment. In particular, acknowledging the subtleties of the often complex, yet unremarkable, details that surround our everyday routines places powerful requirements on any technology that might become embedded in such activities. We have demonstrated that social scientists can provide examples which help reveal what ‘invisible in use’ might mean. The move from this to design is clearly still a major challenge, but there are intriguing possibilities that ethnographically based accounts in this area might not only help clarify concepts, inspire design, or suggest requirements, but might be of value as part of the resulting system.

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