

Unremarkable Computing

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Abstract

In this paper, we seek to contribute to the Ubiquitous Computing agenda by focusing on one of its earliest, but most difficult, design 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. We use some examples of domestic routines to identify a number of insights into what it means for 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 the HCI issues of what will be required to develop technologies that really are “invisible in use”.

Keywords

Ubiquitous Computing, Ethnography; Ambient Intelligence; Tangible Interfaces, Domestic Technology; CSCW

INTRODUCTION

Much of the research on Ubiquitous Computing has been dominated by a focus upon the office environment. From the beginning when Mark Weiser articulated the notion of Ubiquitous 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 ...” [15]

In our current research we have been considering the notion of Ubiquitous Computing in the context of another domain – the home. Firstly, this has been motivated by changes in employment, 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 design vocabulary of the office revolves around tasks,

processes, productivity and functionality, the language of the home is often oriented towards lifestyle, aspirations, emotions, aesthetics and so forth. Yet, as Ubiquitous Computing takes hold, we can expect that computing will increasingly expand from the work domain and will become embedded within home appliances and domestic environments. Consequently these two technology and design traditions are on a potential collision course. Secondly, we have been 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.

The overall goal was to understand how Ubiquitous Computing might arrive and make its place in domestic life. Our strategy in examining home environments has been to first ‘let them speak for themselves’. Our approach has been one of ethnomethodologically-informed ethnography (and as such is part of a growing body of work in HCI and CSCW). The goal here is to understand, pre-theoretically, the actual lived details of phenomena and to bring out the *ethno-methods* [5] and tacit resources whereby things come to look the way they do. This is achieved through *in situ in vivo* observation where the ethnographer seeks to become not just a passive observer, but a competent member in some setting, thereby gaining access to members’ relevances and understandings. In this project one of us participated in the domestic lives of five households over the course of a year and typically spent several weeks with each.

The Glue of Domestic Life

Although our starting point was simply a general interest in domestic environments and ubiquitous computing, as we set about looking at the everyday phenomena of life and work within the home, we were struck by the prevalence of routines and how much turned upon them. We had not set out to analyse domestic routines but it became evident that they were highly significant in home life and had intriguing characteristics. Their significance was such that, in home settings where work was also done, work routines were typically made subservient to domestic routines. Work was seen as a thing that (within certain confines) could 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 ordinary enterprise can be undertaken unhesitatingly. This is especially pertinent in the home where the highly disparate priorities of different family members have to be coordinated without the commonality of an orientation to some shared work objective to bind them together. Routines help

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provide the grounds whereby the business of home life gets done. Routines mean that people can get out the door, feed themselves, put the children to bed, and so on, without having to eternally take pause and invent sequences of action anew or open up their every facet for inspection or challenge or to constantly have to *account* for what they are doing with explanations or rationales.

Previous Work on Routines

There is little empirical understanding of the fundamental nature of routines in domestic life to date, despite their significance (though [8] discusses them in relation to the 'equilibrium' of the home)). Additionally, while [8] (and also [13]) make some tentative suggestions for the design of domestic technologies, no means have yet been found for an understanding of domestic routines to impact the design of domestic technologies in a way which is comparable to the impact that the study of routines in the *office* environment has had on 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' (see for example [4]). However, it was the field studies of researchers like Wynn [18] and Suchman [11] that 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.' Suchman [12] in particular was able to suggest a radically different sense to 'routine' and illustrate the importance for design of taking 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 merely enacted programmatically. A focus upon supporting work with resources rather than automating representations of routines has now become a distinctive characteristic of CSCW in recognition of '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, in CSCW research this is now a well worn path, where the primary focus has remained upon *work* practices and typically the *office*. So, rather than replay here the lessons of CSCW by applying them once more but to the field of Ubiquitous Computing, we intend to put them aside for the time being and take a fresh look at routines and do so through the study of a new domain - the home. It should be said, though, that domestic routines cover a wide range of phenomena with many research implications. Our aim in this paper is therefore a modest one: we seek only to begin to identify, through empirical materials, some of the features of things that have a *routine character* in the home. Our interest is not then in producing a list or taxonomy of routines or a measure of their generality. Our aim is not even simply to compare domestic and office routines. Rather, our aim is to look at examples of things that we might call routine and to attempt to understand what it is that gives these courses of action a routine character (and by looking at examples outside of the office domain we hope to see previously under-explored aspects of this character).

INSTANCES OF ROUTINES

Done in the Doing: the Knock on the Door

Our first instances of interest are two distinct but related 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 the mother, whom we shall call Christine, departs to pick up her youngest daughter, whom we call Susie, from school. They also involve the neighbour (and sister-in-law) whom we call Louise and who has a child at the same school.

Instance 1a:

Christine was 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 fetch Susie from school. She goes into the kitchen through the back door, shuts and locks it and closes the kitchen window, before putting away some shopping that she has left out, 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 nextdoor neighbour, Louise, is already 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 1b:

On another day, 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 nextdoor, 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 1:
"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. Neither of them waits if the other one does not 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 surface. Things can be 'done in the doing' of a knock - such as 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 going on here. In instance 1a, Louise knocks on the door and then walks away without waiting for Christine to appear. 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. That is, for each of the mothers involved, the knock is *just enough* to tell them that the other mother is about to walk to the school.

Opening the Door as a 'Message'

Another otherwise strange feature of instance 1a 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 immediately or that a half opening of the door followed by walking away would be highly accountable, prompting an apology or explanation (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 cause offence or be held accountable. The routine has become honed such that the most minimal of actions has a wealth of significance and well understood mutual accountabilities. In this way, 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 minimally acknowledged.

Context Specific Meanings

We now want to move on to considering how it would have been had the knock on the door 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 is only intelligible 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 local and highly precise intelligibility in such a way as to enable the co-ordination of one specific commonality of routines between two families. The particulars of how these sequences of actions are realised serve as resources for achieving an effectively co-ordinated shared routine. Central to this shared routine is that neither of the mothers 'open up' the operation of it for remark or problematise its unique features (which, in relation to all the many things that knocking on a door and opening a door might amount to, are quite distinctive). In instance 1b for example what is remarked upon is not the practice itself but rather the perfection of this particular realisation. The beauty of instance 1b 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. A knock on the door 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.

This realisation of this routine relies upon the mutual intelligibility of certain very specific courses of action, courses of action that in just about any other set of circumstances might be meaningful in totally different ways. There is also a highly nuanced adaptation of wholly mundane physical and interactional resources such as knocks on doors, and openings of

doors. The result is that some, at first sight strange, happenings at 3 o'clock on a school day can add up to something meaningful yet evidently unremarkable for two mothers from different houses who want to walk together to school. So, to summarise what we have discovered here: Firstly, specific meanings can accrue to certain activities such that they can serve to facilitate the coordination of routines (including routines across households). Secondly, these meanings can be highly particular and only locally intelligible. Thirdly, the shared understandings of the meanings are such that those doing them do not have to account for what it is that they are doing or why. Finally, these activities can be 'just enough' to achieve what needs to be done and it is what is 'done in the doing' (such as giving a message to notify of imminent departure) that is the matter of significance.

Perceptual Visibility and Practical Invisibility: the Alarm Clock

Our second instance of interest is an extract from a study of a freelance language translator working at home. The translator in question, whom we shall call Lucie, lived in a small 3-bedroomed house with her 2 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. This form of translation work is paid by the word and so Lucie 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 since about 6:00 a.m. translating from English into French a text describing a new dieting aid. To begin with her children are asleep upstairs but over the course of this instance their morning routine begins.

Instance 2:

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. It is 7:00 a.m. and an alarm goes off upstairs which she shows no reaction to and continues 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... ».

One feature we would particularly like to draw attention to here is the way she shows no response to the alarm going off upstairs in the child's bedroom at 7 o'clock, despite going to the foot of the stairs to call up to the children a short while later.

Marking Out

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 sitting beside her the alarm going off is a notable enough event for it to be recorded in the fieldnotes. Despite the fact that Lucie regularly commented to the ethnographer about numerous other events, here the alarm passes by without remark.

Having reported upon what Lucie actually did, let us for a moment consider what she did *not* do, what other plausible actions did not happen. For example, when the alarm went off she did not draw attention to it by saying, for example, 'whatever is that?'. To have done so would have *marked out* the

'unusualness' of the occurrence, perhaps prompting investigation or the seeking out of some explanatory account (for instance 'the alarm has been set wrong somehow'). Similarly, she did not comment 'there goes the alarm again' which suggests that the alarm is a regular but still 'notable' occurrence. Alternatively she might perhaps have said something like 'Oh, is it that time already?' through which comment she would not be marking out the alarm per se but rather the alarm would be the thing which prompted her to notice the passing of time, just as other things can prompt such a thought. This would not be an account for the alarm going off but a remark about something else.

She could then have commented in many ways and in doing so could have suggested many things such as marking out how unusual the alarm was, how regularly it interrupts her, what an irritation it is, what it has made her think of and so forth. However none of these happen but instead what happens is that she in no way, shape or form marks out the going off of the alarm – not a twitch, not a blink, not a sigh. If she had commented upon it that would have made it a different phenomena in that through Lucie's total lack of reaction to the alarm she displays her orientation to it as something wholly *unremarkable*. By *manifestly* not marking this out 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?* Furthermore, this is something she is *able* to do. That she can choose to not mark out the alarm and to *treat it as* something unremarkable makes it evident that there is then nothing inherent in the going off of the alarm that obliges her to treat it as a notable or remarkable event. The alarm is *unremarkable*.

This is not to say that people never notice elements in their routines. One can carefully watch that a pan of water does not boil over when cooking without provoking remark because it is appropriate to do that within the routine. In this way something can require concentration or careful attention but *as part of* the routine, in a manifestly unremarkable and evidently appropriate way. In this way it is *already* intelligible *in terms of* the routine and needs no further account. However the 'routine' character of events is fundamentally undermined when to pay manifest attention to them prompts some kind of special account for that attention. To mark something out is in many ways then the exact opposite of something having a routine character and to mark out something that is normally routine has the consequence of generating a requirement to produce an account, explanation or rationale.

So here we have some further orderly features of what 'routine character' might consist of in that the elements of routines (understandings, practices, artefacts, courses of action, etc.) achieve the status of becoming unremarkable by virtue of having been made routine. Consequently, they can be apparently unnoticed. Additionally, where they are obviously paid attention to this is either (i) evidently appropriate in terms of the routine and hence equally unremarkable or (ii) it is remarkable and, for those engaged in a routine to remark upon the routine itself, is an accountable action.

Import and Implication

However, although the alarm going off has the status of something 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 not acting

upon it highly accountable. In this way, it is *used*. It is a resource. It can, for example, serve to initiate other features of the everyday morning routine, such as getting out of bed, going to the bathroom, getting dressed and so forth. That it is used is revealed by Lucie's subsequent movement to the foot of the stairs to call up to the children. This also suggests an orientation to the alarm as something 'nodal', a thing upon which many other things may turn. So not remarking upon the alarm going off is certainly not dismissal.

Similarly, though aspects of routines may never be directly remarked upon, not responding to their implicativeness is accountable, and accountable in the very terms of what is usually unremarked. For example not getting up in the morning might prompt a remark such as 'didn't you hear the alarm going off?'. So in the example we have described it is not the case that she has not noticed or is not attending to the alarm going off. *Rather she is not marking out through some visible display that this is notable because to display that 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). Should an alarm fail to go off that failure could itself be quite specifically marked out. Alarms then can be perceptually visible yet practically invisible *in use*, as part of what has been made routine. Relatedly, they can be perceptually non-existent (through, for example, failure to go off) yet practically marked out. What matters about the alarm here is not so much its perceptual character as its significance, a significance that can be made explicit should the alarm ever fail.

So again we see that an orderly aspect of things with a routine character is that they can serve as resources for the mutual co-ordination of unremarkable activities (in this case, the activities of getting up and, in the previous instance, the activities of setting out on a task together). These resources are mutually available and mutually accountable for those involved in the routine. Also things do of course go wrong in domestic life, alarms can fail – but failure, in contrast to accomplishment, *is* remarkable and the elements held to account when part of a routine fails are the very ones that are unremarkable at other times. Evidently not marking out an element of a routine is not equivalent to not noticing that element. In this way, artefacts that are implicated in routines can be perceptually available yet practically invisible in use. And, finally, a feature within many routines is that there are nodal occurrences that are implicative for things that follow.

Knowing Others' Routines: Going to the Coffee Shop

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 meshing together highly distinct orientations and goals, where it may be that one of the interactants is *never normally part of that routine at all*.

The instance is taken from an ethnographic study of the work of a freelance website designer and graphic artist, whom we shall call Michael, 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 call in to see him later and talk about things in more detail.

Now, so far we have looked at examples of routines that are oriented to as resources for activities 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 John's 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. Here 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 family 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 his morning coffee as a thing he did by habit to facilitate someone like a visitor finding him, but such a *mentioning* is, importantly, 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 involved in John's routine that an element of John's routine can be, for Michael, a matter of comment. Thus Michael is not accountable for having made something notable and significant out of what, for members of John's family, is necessarily taken for granted. Furthermore, in this specific instance Michael is also not engaged in routine activities himself; on the contrary, his actions are specifically occasioned (by not being able to complete a 'to do' item and not being able to speak to John on the telephone) and thus Michael has explicit motivations in marking out an element of John's routines which he has knowledge of. So here we have someone who is not pursuing a routine of their own but is using what they have explicitly noted about someone else's routine as a resource to accomplish a particular course of action.

Doing and Describing

What we are not saying, however, is that people 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 provide a description of a routine and justify it in the context of activities like being interviewed. In these cases, though, giving a description of a routine is specifically *occasioned* – being asked, for example, is the motivation to

answer and the context in which you are asked guides what answer is appropriate. The occasion that prompts the account also prompts the picking out of details of a routine and imbues those things with certain significances. Importantly then, *an occasioned account of a routine is different from the actual realisation of a routine* – where to give something marked significance is wholly contrary to just taking things for granted. Indeed things that are taken for granted form the very *background* against which one might take note of and mark out other activities, activities that *are* significant, relevant, distinctive or notable and are so according to the occasion that is prompting the description.

So we can note here that there are circumstances for explicitly remarking upon both one's own and other people's routines, but, importantly, these remarks are situationally occasioned. 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. Another way shown in this case is where the availability of John's routine for Michael's inspection was a matter of Michael's own *noticing*. He had discovered it through his own recurrent visits to the same coffee shop.

So, to summarise, people can provide accounts of their own routines and people can be interested in the routines of others. Providing an account of a routine however is occasioned and what is described as relevant within the routine is bound up with that occasion. In addition, there are appropriate motives for displaying interest in someone else's routines and such interests are also specifically occasioned (e.g. by needing to talk to them). Knowing the routines of others can serve as a resource for an activity and the routines of others can be discovered through occasioned accounts and through noticing.

SIGNIFICANCE FOR UBIQUITOUS COMPUTING

We have 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 routines are invisible in use for those who are involved in them. Returning to the agenda set by Mark Weiser (but of course developed by many others since) we wish to consider what it is about this unremarkable aspect of routines that could help us develop Ubiquitous Computing that is invisible in use and in its own way unremarkable. This aim is again well articulated in Weiser's initial vision [16]:

"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."

Things with a routine character may then have many of the qualities we are aiming for by being tacit and calm in that they are not 'dramatic' and do not command attention except when they need to. They are seen but unremarked, used as resources for action, and themselves use everyday resources (doors, alarms, coffee shops, etc.) in ways that have a wealth of significance but have been made equally unremarkable. However, just how to go about designing computing "so embedded, so fitting, so natural" remains, we would suggest, unsolved. In fact a central point of this paper, to which we now wish to turn, is that many of the current approaches to solving this do not seem to match with what we have observed about routines so far.

Use and Inherent Qualities

Let us take as a first point the sense of computing as something that could ‘disappear’. Figure 3 is an attempt to convey this idea from a research project on ambient computing [9] in which a contrast is made between the image on the left of our current world and the image on the right of a future world.



Figure 3: “All sorts of computing devices will disappear into the background of our everyday lives” [9].

This is clearly trying to visually convey what might be meant by ‘disappearing computing’ and we are not unsympathetic to such attempts. However these types of images tend to suggest a 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 2 involves a perceptually demanding device yet one that has been made routine. The alarm is not smaller or quieter or somehow perceptually ambient but rather, as a function of use, has been made unremarkable. Perceptually it remains an alarm but its significance has been made unremarkable. Similarly, an alarm not sounding at all could very well be the remarked upon event.

The notion of “invisibility in use” is a difficult idea. Its full implications for the design of technology have not yet been discovered. Often “invisible in use” is understood as meaning literally (perceptually) invisible as enabled by the miniaturisation of computational technology that allows devices to become smaller and (perhaps) perceptually less visible. However, we believe that the design goal that was originally envisaged as part of the Ubiquitous Computing program requires a different understanding (though one which may not have been helped by early examples, such as “The Dangling String” [17] which can be read as concerning perceptual psychology of “peripheral sensory processing” [17], rather than issues of a resources in action). Clearly there *are* perceptual qualities that may be involved in creating an “invisible-in-use” phenomenon (an alarm is no use unless you can hear it). Yet we feel that too narrow a focus has emerged upon the perceptual qualities of a device rather than upon how people embed these perceptual resources into routines such that they are unremarkable in use. We feel this sense of “invisibility in use” is already prefigured in the attempt to turn attention away from the search for better ‘inherent qualities’ of computers. What is sought is not a computer that is just more intimate [14] or even more intelligent [15] 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.” [16]. Similarly inherent perceptual qualities regarding visibility are not the same as invisible in use. Computers that have visually disappeared, or that produce perceptually ‘softer’ notifications are not necessarily any 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 interaction but which could not be seen or heard could be *more* remarkable, *more* present than before. The

challenge for design is to go beyond simply focusing upon the perceptual qualities of devices and to make computational resources that can be unremarkably embedded into routines and augment action.

Augment the Action

Here then we wish to move on to our second point derived from our studies of domestic routines – that it is actions that need augmenting not artefacts per se. Artefacts may need augmenting in order to augment actions, of course, but those artefacts are to be in service of the actions and their augmentation should be motivated by their role in those actions.

In fieldwork instance 1a it is clear that 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 everyday features of the tangible world that are being manipulated using mundane competencies people have for touching and moving surfaces. However, it is also clear that 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 door artefact so as to make a sound audible to those on the other side of the door. Here it is also a means to coordinate actions and make others aware that you are ready to begin a routine. These are the significances of these actions. Furthermore, it is apparent (as in instance 1b) that there are other ways of achieving these aims and occasions where these artefacts need not be used at all.

This suggests to us that some caution is required about moves to augment the tangible artefacts used in activities. Again we are sympathetic to the intent underlying the tangible interface paradigm. Firstly, in attempting to make computing “so embedded, so fitting, so natural” augmenting physical artefacts becomes highly appealing (especially if these provide visible interaction mechanisms for perceptually invisible computer hardware). Secondly, the tangible interface approach is a perfectly coherent HCI approach. Manipulating physical objects is one of people’s everyday competencies and more generally available than, say, abstract computer commands and software applications. There is a logic behind developing tangible interaction mechanisms just as there has been a logic behind designing other such everyday competence-based interaction paradigms: spatially based systems (like rooms [7] or virtual environments [1]); graphical interfaces and visual-symbol based interfaces; and some of the earliest HCI research assessed command languages relative to natural language learning as an everyday human competence (for example, [10]). Such everyday competencies are deployed, however, *so as to* communicate, organize, coordinate, etc. Augmenting a door artefact would only be a sensible design choice once one understood the (local and specific) significances that this artefact and the associated action of ‘knocking’ has. Sometimes what is ‘natural’ is highly situated and thoroughly social.

For us, then, the point here is not that interaction with computation *may* be mediated through tangible mechanisms [2] or through the augmentation of everyday tangible objects (such as the Media Cup [6]) or even through natural language, speech or gesture. Rather, the key point 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*.

Focusing only upon the door artefact enables only a (literally) surface interpretation of what is going on and what people are doing. Augmenting artefacts needs to be in the service of both actions done with those artefacts and what is accomplished through those actions, what is “done in the doing”. In instance 1b 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, 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 problem is 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. For us, this emphasizes the importance of what can be called “user semantics” and here the target is the area that is between and deliberately separate from (i) how system entities connect to each other and what they know about themselves and others (ii) how users interact with the system through interaction mechanisms. User semantics is rather what the user makes of the computational resources (primitives, combinations, constraints etc) and includes any accounts or representations the computational system gives of itself [3]. 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 particular danger of this middle area being slipped over if issues of new user-level semantics are 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 could choose to embed within a door some mechanism that displayed a personalised newspaper, or debited a credit card or changed channels on a television whenever someone knocked on it. These might or might not be desirable additions to the functionality of the door. What matters, however, is that they would change the semantics of the door, regardless of how useful or easy to learn that might be. Furthermore, we have seen in instances 1a and 1b 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 whilst some uses of some doors by some people at some times might lead one to want to augment those doors such that, say, 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 offer nothing to what was done with the door in instance 1a.

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

Supporting routines themselves

Finally, as we turn towards augmenting actions and the sense of those actions within sequences of actions, then routines themselves become a topic of interest. As we have noted routines are sequences of action that are simultaneously unremarkable and yet *central* to the realisation of domestic life. The question is what will it really mean for Ubiquitous Computing to fit comfortably within everyday routines and augment them without losing or disrupting the qualities that make them what they are. Similarly, what would it mean for systems to utilise knowledge of peoples’ routines themselves in order to deliver calm and *context-sensitive* support?

We have noted that in the office environment Office Automation systems failed to appreciate the subtlety of the status of representations of routines and the impact upon this when they became embedded within systems that constrained and determined how work flowed. Consequently we suggest that care may be needed to ensure that systems aimed at augmenting everyday routines do not transform the unremarked nature of doing routines by marking them out through supporting them. It could be that marking out actions within routines is the very thing that disrupts the doing of routine sequences of actions. Systems must be designed such that background is not made foreground, routines are not made episodic, and the matter of course does not become a matter of comment. Is developing Ubiquitous Computing or Context-Aware Computing that supports or uses an understanding of routines therefore impossible? We would argue not. Routines are resources for action and knowledge of others’ routines can also be resources for action and interaction. They are knowable, teachable and breachable. To some extent the same may be true for systems’ comprehensions of routines. Firstly, we believe that much can be learned from the details of routines - such as in instance 2 where we noted how within many routines there are *nodal* occurrences that are implicative for things that follow (such as the alarm clock or the knock on the door). These may be, for example, utterances that open up conversations or close them down, actions that initiate sequences or conclude them. From a Ubiquitous Computing point of view: are these useful points to detect? are they points for potential augmentation? is an intervention that has to make these points more explicitly marked out less disruptive than another design choice?

Secondly, we suggest that the status of user accounts of routines needs careful consideration. 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 (with what is noted as relevant within the routine being bound up with that occasion). Put simply, users doing routines is different from users describing routines. The point then is not to deny that users can, if required, provide a description of a routine and neither is it to suggest that this description is somehow ‘false’ or that asking users is a

'mistake'. Furthermore such descriptions may be very useful for systems to work with. Consequently this is not an argument against systems that, for example, ask users to script sequences of routine action. Relatedly this is not an argument against systems that attempt to notice patterns of activity, as we have observed that this is exactly one of the ways in which people learn of others' routines in useful ways. However, this is an argument for a clear conceptual understanding of the difference between being involved in giving a description or account of a routine and being involved in doing the routine. To take this further, it may well be that systems which intend to support the *doing* of a routine will be highly disruptive if in the course of the doing of the routine they require the user to switch to *description* activities. To do so would be to effectively pull the user away from doing their routine and to call them to account for it, to remark upon its elements and to thereby require an explanation of their significance.

CONCLUSION

We have shown 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. (Indeed a number of our reviewers drew lessons for HCI in general). In particular, recognizing the subtle character 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 provided examples that help reveal what 'invisible in use' might mean but acknowledge that a great deal of research remains to be done in order to move from this to actual designs. We believe that there are deep challenges ahead in trying to provide unremarkable computing for unremarkable routines. In this paper we have attempted to articulate some of these challenges and take a small step towards suggesting how they might be addressed.

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