Futures in the making: practices to anticipate ‘ubiquitous computing’

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Abstract: This article addresses the discourse for a proactive thinking of futurity, intimately concerned with technology, which comes to an influential fruition in the discussion and representation of ‘ubiquitous computing’. The imagination, proposal or playing out of ubiquitous computing environments are bound up with particular ways of constructing futurity. This article charts the techniques used in ubiquitous computing development to negotiate that futurity. In so doing, this article engages with recent geographical debates around anticipation and futurity. The discussion accordingly proceeds in four parts: First, the spatial imagination engendered by the development of ubiquitous computing is explored. Second, particular techniques in ubiquitous computing research and development for anticipating future technology use, and their limits, are discussed through empirical findings. Third, anticipatory knowledge is explored as the basis for stable means of future orientation, which both generates and derives from the techniques for anticipating futures. Finally, the importance of studying future orientation is situated in relation to the somewhat contradictory nature of anticipatory knowledges of ubicomp and related forms of spatial imagination.

Keywords: anticipation, anticipatory knowledge, future, spatial imagination, technology, ubiquitous computing

1. Introduction

This article addresses the future orientation intimately concerned with technology development. I suggest this comes to an influential fruition in the discussion and representation of ‘ubiquitous computing’, a research agenda that, broadly, envisages people, places and things intermediated by a range of internet connected appliances and services. The purpose of this article is to examine how particular visions of these types of future technology use are constituted. Such research attracted significant financial support in private industry, in the form of investment in research groups, and from governments, in the form of targeted funding. In this article, then, I aim to attend to a technically situated ‘presence of the future’ in relation to the ‘living present’ (pace Anderson, 2010b). This article focuses on the groups involved in ‘ubiquitous computing’ research and development (R&D) to negotiate that futurity. The discussion therefore engages with recent geographical debates around anticipation, future orientation and technology use. The empirical basis of the work discussed is ubiquitous computing R&D in the corporate sector, studied through interviews in Silicon Valley, California, in 2008[1].

This article advances the social sciences' engagement with ubiquitous computing, which has been somewhat limited (see: Andrejevic, 2005; Crang and Graham, 2007; Dodge and Kitchin, 2007; Galloway, 2004). Indeed, as the guest editor of a recent 'pervasive computing'[2] themed journal issue suggests: 'we have quite a way to go before we develop a richer understanding of what is happening at the intersection of space, sociality and pervasive computing' (Dave, 2007, page 382). Interestingly, much of this engagement takes the 'visions' of the future used to represent ubicomp research projects at face value and analyses their possible implications rather than problematising the production of such visions (for example: de Souza e Silva, 2006; Paay et al., 2007). This paper explicitly addresses this issue through its central aim of examining how particular visions of these types of future technology use are formed.

In geography there have been a small number of engagements with ubiquitous computing as such (for example: Crang and Graham, 2007; Dodge and Kitchin, 2009). Following a call to 'investigate geographies of software' and the 'automatic production of space' (Thrift and French, 2002), and furthering important work by Stephen Graham (1998, 2005; Graham and Marvin, 2001), Martin Dodge and Rob Kitchin (2005, 2007, 2009) have

[1] Interviews were conducted with research industry experts and employees of industrial research laboratories of technology corporations, including HP Labs, Intel, Nokia, and Fuji Xerox. The interviewees have been anonymised as Researchers A, B, C, D and E.

[2] A number of terms are used within cognate research arenas, such as 'ambient', 'pervasive', 'ubiquitous' and 'urban', which typically precede the terms: 'computing', 'intelligence' and 'media'.

conducted prominent work concerning the influence of 'code' on the mediation and navigation of space and place (in particular, see: Kitchin and Dodge, 2011). The manifold geographies of data have also been addressed by geographers from a range of standpoints (for example: Bingham, 2001; Budd and Adey, 2009; Thrift, 2004; Wilson, 2011; Zook and Graham, 2007). This article seeks to extend work concerning geographies of technology with a detailed discussion of ubiquitous computing as a form of spatial imagining. In particular, the basis for future orientation within ubiquitous computing R&D is investigated as forms of anticipatory knowledge.

To examine this form of technologically focused future orientation this article is structured in four parts. The second section frames the discussion of ubiquitous computing in relation to geographical investigations of technology and foregrounds the importance of the forms of spatial imagination engendered by the development of ubiquitous computing. The third section focuses upon techniques of anticipation that emerge from empirical evidence and how they exist in tension with very pragmatic concerns. In the fourth section, the concept of anticipatory 'knowledges' is discussed in relation to the empirical discussion in section three. In conclusion the importance of studying future orientation is situated in relation to the somewhat contradictory nature of anticipatory knowledges of ubicomp and related forms of spatial imagination.

2. Spatial imaginations of ubiquitous computing

There are many ubiquitous computings (Greenfield, 2006, page 11). Some are arguably entwined with everyday urban life as it is lived today, as Dourish and Bell (2011) and Kitchin and Dodge (2011) have usefully catalogued. Ubiquitous computing, or 'ubicomp', continues to signify an arena of academic and industrial research, several conferences (for example: Bardram et al., 2010), several journals (for example: *Personal and Ubiquitous Computing*), and the topic of a number of books that one might catalogued under 'business' or 'popular science' (for example: Begole, 2011; Greenfield, 2006; Kuniavsky, 2010; McCullough, 2004; Sterling, 2005). However, as has been suggested elsewhere (Bell and Dourish, 2007; Dourish, 2004; Dourish and Bell, 2011; Kitchin and Dodge, 2011), the various people and organisations that have propagated ubicomp as a discourse have also contributed visions of a technological future that have been rather influential. From the outset, the details of ubicomp have been positioned in the future. In 1991, an article entitled 'The Computer for the 21st Century' written by Mark Weiser, director of the Computer Science Laboratory at the Xerox Palo Alto Research Centre (PARC), popularised the research agenda in the guise of a vision that many have subsequently adopted.

As an arena of research within Computer Science, ubiquitous computing has attracted significant capital investment from both commercial interests and public bodies. In the corporate sector, for example, there has been work on 'Active Badges' at Olivetti; the IBM 'Pervasive Computing' work with early web-enabled mobile phones; and Hewlett Packard's 'CoolTown' work to put a web server in everyday electronics devices (for a more detailed review of such work see: Dourish and Bell, 2011, pages 14-19; Want, 2010). In the public sector, for example, the 'Ubiquitous Computing Grand Challenge' identified by the UK Computing Research Committee was significantly funded by the EPSRC in the guise of the EQUATOR 'interdisciplinary research collaboration' (over £10million between 2000-2006, see EPSRC grant GR/N15986/01). Also, the European Union 'Disappearing Computer' initiative saw the distribution of over €40million between 2000-2004 (see: Streitz et al., 2007, page xi). Indeed, as

Dourish and Bell (2011) assert in their book concerning the 'mythology' of ubicomp:

> 'by many accounts ubicomp has been tremendously successful. It has been a successful research endeavour. In addition to being a topic in its own right, it is also a central aspect of the research agenda of many other areas of computer science research... Furthermore, it has been successful as a technological agenda, meaning that Weiser's model of a single person making use of tens of hundreds of embedded devices networked together is a reality for many people' (Dourish and Bell, 2011, page 91).

However, despite this success and for the purposes of this article, some work of definition is necessary: 'ubiquitous computing', or 'ubicomp', is a research agenda or field, spanning academic and corporate research, whose aim can be understood as the construction of environments of computational plenty. Having said this, as Computer Scientist Gregory Abowd notes in his *Foreward* to *Ubiquitous Computing Fundamentals*: 'One of the strengths, and one of the challenges, of "ubicomp" is that it is hard to pin down exactly what the intellectual core is.' (Abowd, 2010, page vii). 'Ubicomp' binds together a diverse and varied collection of research practises—from ethnography (see Dourish, 2006) to network design (Tayal and Patnaik, 2004) and software engineering (Decker et al., 2005).

Historically, the term 'ubiquitous computing' originated from Mark Weiser, director of the Computer Science Laboratory at Xerox PARC in the 1980s and 1990s. He described an ambition to facilitate the diffusion of computers throughout the everyday lived environment. In the first sentence of Weiser's highly cited *Scientific American* article 'The Computer for the 21st Century' he sums up his ethos for ubiquitous computing:

> 'The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it' (Weiser, 1991, page 66).

To facilitate an understanding, or knowledge, of what it would be like to live with this '21st Century' computing, Weiser wrote a speculative story in which he describes the fictional future lifeworld of 'Sal':

> 'Sal picks up a tab and "waves" it to her friend Joe in the design group, with whom she is sharing a joint assignment. They are sharing a virtual office for a few weeks. The sharing can take many forms—in this case, the two have given each other access to their location detectors and to each other's screen contents and location. Sal chooses to keep miniature versions of all Joe's tabs and pads in view and three-dimensionally correct in a little suite of tabs in the back corner of her desk. She can't see what anything says, but she feels more in touch with his work when noticing the displays change out of the corner of her eye, and she can easily enlarge anything if necessary' (Weiser, 1991, page 75).

Of course, the story of 'Sal' not only situates the forms of technical encounter in a recognisable world, but also in a particularly American, largely middle class, context. The identity politics of Weiser's (1991) story are outside the scope of this article but it is important to note that such forms of future orientation are culturally situated.

Since the earliest days of such research, ubicomp discourse has been a research agenda with prolific envisioning of futures. In their recent book, *Divining a Digital Future*, Paul Dourish, a computer scientist, and Genevieve Bell, an anthropologist, examine the continuing agency of Weiser's vision. They suggest of his 1991 article that:

> 'Rhetorically, Weiser situates the research activities that he describes as initial steps upon a path of technological development inspired by an explicit vision of possible future relationships between people, practices and technology' (Dourish and Bell, 2011, page 20).

As Dourish and Bell (2011, pages 20-21) go on to assert Weiser's article was doubly influential, not only did it describe a research agenda that many went on to adopt but it also set a rhetorical tone that many have adopted. The ways in which ubicomp researchers anticipate may purport to elucidate futures but they also speak significantly about the present in which they are created. A future of ubiquitous computing is a process, in this regard, and not a place.

Within the practices of R&D in ubicomp, I have argued elsewhere (Kinsley, 2011) that, as a discourse, anticipation is performed according to a range of logics through which attempts to stabilise how particular futures play out. This stabilisation is achieved by positing a knowledge of the future, which can be acted upon. Such knowledge emerges from techniques for addressing forms of future technology use. In the next section I discuss some techniques used in R&D to make futures present.

3. Anticipating ubiquitous computing

Actions that are anticipatory in nature involve rendering futures apparently actionable. Anderson describes 'the presence of the future' as the result of anticipatory techniques that 'do more than gather the knowledge necessary to know futures' (Anderson, 2010b, page 783). Anticipatory techniques are a means of establishing the presence of what has not happened and may never happen, an 'indeterminate potentiality' (Massumi, 2007, page §13). As Adam and Groves (2007) argue, 'futures' are frequently embodied, told, imagined, performed, wished, symbolised and sensed. However, making futures present, if we follow Anderson (2010b), is somewhat paradoxical. Futures are apparently made present as objects such as reports on trends, stories or models, and are felt as anxieties or hopes but those futures do not cease to be absent insofar as they have not and may never happen. Ubicomp as a discourse and research endeavour exemplifies this paradox through its, sometimes conflicting, rhetoric and R&D techniques.

The purpose of this section is to examine the techniques of anticipation for ubicomp in the context explained in section two. I explore two methods used in ubicomp R&D to negotiate future orientation and explore where this rests in tension with other, perhaps more pragmatic, concerns. Beyond Anderson's (2010b) discussion of governmental anticipatory practices for perceived threats, it is also necessary to attend to other, somewhat different, performative modes of anticipation (such as: Suchman et al., 2002), and importantly to the limits to their scope. There is a significant heritage of such future orientation in technology design and development. The use of 'scenarios' as a design method to outline and perform possibilities is well documented (for example, see: Carroll, 2000, 1995). Two leading research centres are well known for having implemented particular kinds of future oriented practice. PARC, the industrial lab where Weiser formulated his vision for ubicomp, is known for its 'time machine research':

> 'A time machine is a privileged platform that creates for today an environment anticipating what will be widely available in the future. You become an early pioneer of the future. You can explore it first, map the territory, and harvest the first results' (Stefik and Stefik, 2004, page 174).

Equally, a similar 'demo or die' culture at the Massachusetts Institute of Technology's Media Lab was documented in the widely cited book 'The Media Lab' by Stewart Brand (1988), which carried the subtitle: 'inventing the future at MIT'. These are not solely rhetorical strategies, physical demos and material prototypes are often made, but neither are they solely instrumental. As I demonstrate in this section, making futures present takes place in different registers, of representation, performance and specification, and produces particular kinds of knowledge of those futures upon which development strategies are made possible.

My focus in this section is on two methods, revealed through fieldwork, that are employed in ubicomp research to anticipate contexts and uses for prospective technologies: imagining and enacting futures. I go on to discuss how they relate to broader disciplinary concerns and the destination of the research produced. The purpose here is not only to explore how the methods are practised but the context for their deployment and those specific contexts that give them shape and meaning.

3.1. Imagining futures

Future technology uses, and the worlds in which they take place, are sometimes imagined and described through stories and images as a part of the research process. Desired, feared or uncertain futures have long been made present through creative acts of storytelling and science fiction (see: Dourish and Bell, 2008; Kirby, 2011; Kitchin and Kneale, 2001; Rose, 2000), particularly in relation to technology, as well as more formal techniques of foresight such as horizon scanning, scenario planning and visioning (see: Brown, 2007; Lösch, 2006; Meadows and O'Brien, 1998; Winner, 2004). The technique of imagining futures is most often expressed in the form of storytelling to contextualise and to lend a reality to a speculative technology. Imaginative renditions of possible futures can be ambiguous in purpose and, as Researcher B of Nokia Research suggests, it is important for the researchers that create and use them to ask themselves what that purpose is:

> 'these visions form some kind of future scenario, are they visions that are meant to be, are they exemplary of some kind of desired future? Or are they actually, they can be feared futures… or [they] can just perhaps be considered, for the sake of research, for articulating a domain' (Researcher B, Nokia Research Centre).

Consider briefly the story of 'Sal' with which Mark Weiser illustrated his vision for ubiquitous computing in the 21st Century, discussed in section two. Equally, scenarios are used to illustrate ideas in introduction to articles and papers in ubicomp research. Stories are employed to draw in the reader, to evoke a particular type of future and to persuade readers of its value. Indeed, the Science Fiction writer Bruce Sterling, in a guest piece for the Association of Computing Machinery journal *Interactions*, argued for a mutual exchange of ideas, between interaction designers and writers, through forms of 'Design Fiction' (Sterling, 2009). Not only are futures imagined in story form but they are also imagined in images through videos (Kinsley, 2010). These representations can become a double-edged sword, as an informant suggests:

> 'in the particular setting of research that needs to be justified or funded by somebody, a vision is useful because [...] it provides that powerful, sort of, visual shorthand, that can get a funding agency or a company excited about something. Which is good, because it keeps the money flowing, right? But [...] you can kind of get it wrong that way too' (Researcher C, formerly of HP Labs).

Imaginative representations of the future can become a powerful 'visual shorthand', as Researcher C suggests, but they can also become too static and outlive their usefulness. However, imaginative renditions of potential futures can be a device for rallying a particular group to certain ends.

Consider one final example of the deployment of techniques of imagination; a set of 'visions', produced by PARC, that describe a future of 'harmonious interaction' with and through technology that would allow people to

> 'communicate, learn, share, create and access information, as well as interact with objects in the physical environment, spontaneously and effortlessly as they go about their everyday lives' (Begole and Masuoka, 2008, page 635).

The vision of the future represented here draws heavily on an analogous comparison with characterisations of 'Eden' as a perfect environment in which to live. As we learn from one author of this 'vision', it is not one but, in fact, several imaginative representations of a possible future that fit together:

> ''harmonious interaction' is really just an umbrella vision and the three sub-dimensions in that are more what we pay attention to on a day to day basis: 'pro-activity', 'natural interaction' and 'ubiquity'. Within those we also have sub-projects, like the 'natural interaction' [dimension],

> there's a piece of that which has to do with making it easy to use your mobile device and that has to do with using sensors to detect your needs. That feeds into the 'pro-activity' [dimension] too, having detected [a need] then satisfying that. That's more at the level we operate, when we're planning things out. So, we've said: Here's this umbrella objective, here's the three ways we're going to attack that problem, because the problem is not concrete enough to solve directly. It's just this [...] quite amorphous goal, so here are three strategies, here's our three bets, on how it'll be accomplished, and that's what we focus on, day to day' (Researcher E, PARC).

The imaginative representations, or 'visions', thus become tools that allow for the direction of particular strategies in day-to-day practises of R&D. In the case of the group at PARC, knowledge of a particular future is enacted through the sense of direction provided by the imaginative representation of a future. These techniques facilitate a form of spatial imagination into which the production of specific prototypes or experiments might subsequently be contextualised. The work that techniques of imagination do here is not to necessarily predetermine the future but to formulate particular spaces of possibility into which established techniques of development can be directed.

3.2. Enacting futures

Futures are also apparently made present through practises that stage the possible through some form of acting, gaming or pretending. Here the potential future of technology use is made present and rendered actionable 'as if' an as-yet unmade technology is, instead, a finished product. Particular forms of play-acting create 'anticipatory experience' by arranging material objects or environments 'as if' they are the desired technology in finished form. This form of acting out, as with other forms of anticipatory action (see in particular: Budd and Adey, 2009), can be understood as a form of simulation[3]. Indeed, ubicomp

[3] Simulation is an important issue in the contemporary technoscientific milieu, for example: it is addressed by Patrick Crogan (2011) as the underlying logic for modern military strategy and the kinds of cybernetic representations of systems thereby employed, which have been developed

designer Mike Kuniavsky devotes a chapter to it in his book *Smart Things: Ubiquitous Computing User Experience Design* (Kuniavsky, 2010). The use of scenarios in technology design also relates to a broader discourse of foresight in which scenarios are employed in precautionary and pre-emptive strategies for natural disasters and terrorist strikes (see: Anderson and Adey, 2011; Collier, 2008).

Several techniques have been developed in technology development to facilitate the production and enactment of 'as if' future technologies, including 'lightweight' or 'paper' prototypes and 'Wizard of Oz' techniques (Carter and Mankoff, 2005; Dahlbäck et al., 1998; Salber and Coutaz, 1993; Snyder, 2003). 'Paper prototypes' involve using rudimentary sketches on paper of a particular interface for a technology that user is invited to interact with alongside a researcher (Snyder, 2003), who performs the interaction 'as if' they were the computational elements of the technology. 'Wizard of Oz' techniques for prototyping are methods for simulating the use of a technology by giving a user an apparently operational device that is, in fact, being manipulated remotely by a human, for example acting as an 'intelligent user interface' (Dahlbäck et al., 1998). These techniques are imaginative but also use the capacities of embodied interaction more explicitly. They have several functions, but are principally employed in the context of experimenting where there is significant uncertainty. Although the techniques for enacting futures differ in detail, they generally involve staging the use of a specific possible technology in a particular context.

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into globally successful forms of game-play. Manuel De Landa (2011) has also recently identified computer simulation as both a means to test philosophical propositions and as an ontogenetic source of emergent forms and behaviour.

The experience of using a technology 'as if' it were a functional device an be achieved through 'lightweight' or 'paper' prototypes. 'Paper prototyping' is 'a widely used method for designing, testing and refining user interfaces' (2003, page 3). Proponents of paper prototyping suggest it offers a fast means of providing a reasonably 'deep' experience of a potential technology with the ability to rapidly iterate through versions of the design (see: Beyer and Holtzblatt, 1999; Snyder, 2003). However, in light of the experiences of Researcher D, of Fuji-Xerox Palo Alto Lab (FX PAL), it is evident that the potential futures enacted are not always desired:

> 'I did some experiments using [...] paper prototypes of [a particular technology] and [...] I found that [...] the direction I went in once I had actually started getting some interactive technology into peoples' hands ended up being so drastically different from any of the scenarios that I built beforehand that it seemed not as important to ensure that scenarios are all that great, you need to have some general direction of course and some idea, but you need to not be married to it and not take it too seriously... because you really don't know what it is you've actually done until you've put it in play' (Researcher D, FXPAL).

Acting out potential technologies provides a direction without some of the specificity of the techniques of 'imagination'. The researcher is opening a space of potential that is perhaps only stabilised in the actions of others—the 'users'. As Researcher D suggests, there are also limits to pre-defined scenarios. The staged contexts of enactment may sit in tension with the unscripted, performative, interpretations of potential users. Enacting futures in this way does not necessarily have to be prescriptive, when the aims are to capture potential development trajectories. Interestingly, an alternative version of this technique was also discussed as an evolution of the researcher's R&D practices:

> 'Sketches are exploratory, [...] you are just trying to get a handle on an idea, you have no real comparison [...] in many cases, you would just create a variety of different designs and then have people evaluate them and... you'd always use people who have lots of experience doing this [...] not using people who're developing it but people... from outside [...] and have them come in and evaluate these different platforms' (Researcher D, FXPAL).

There are clearly limits to the enactment of a potential technology. Following Researcher D, the 'people who have lots of experience' reassert control of the validation of the potential future through expert opinion. A particular expertise is invoked as a condition of the action. Equally, the researcher has modified their practice such that they are not necessarily anticipating the technology use themselves. The 'anticipatory action' is ceded to the 'users' through their evaluation of multiple potential devices or systems. Enacting a form of future technology use, for example through paper prototypes, allows the technology being used 'as if' it were actually functional to be questioned and re-imagined 'as if' it functioned otherwise. The results can be subsequently fed into the generation of prototypes for product development. For Researcher D these methods were oriented towards identifying technical processes that could be patented. Thus while the space of enactment may provide an occasion for experiencing how a future technology might be used, it is also a space in which potentiality is somewhat wrestled over.

4.3. User-centred design and the inference of futures

There are, of course, a host of techniques for 'invention' and 'innovation' that are not concerned with identifying futures as such but instead focus on identifying problems to be solved or gaps in a market. There are established and widely used methods for identifying 'problems' and 'needs', which originate from engineering methodologies, specifications of which can be found in many Human Computer Interaction (HCI) textbooks (for example: Sears and Jacko, 2008; Sharp et al., 2007). Solely pragmatic 'solution identification' techniques can be seen as a-temporal. Such techniques are not anticipatory, insofar as they are not tied to a particular type of future, and they could be transplanted into any time/place, according to the considerations of the designers. The 'User-Centred Design' techniques originating from more 'orthodox' HCI practices remain widely practiced as a part of ubicomp R&D. User-Centred methods for specifying particular scenarios of technology use were expertly summarised by a senior researcher at the Nokia Research Centre:

> '[Y]ou could describe the process like this – number one […] who is your user? That's the first question that you ask yourself. And then, number two what task are you trying to support? Or what problem are you trying to solve… for that user? And then, once you have those two questions answered you can start to design a system to address ah, the user and that task, or address that problem for that user. So, you might be able to characterise that as, you know, problem centred design. Where I have these problems and I have a problem space and what types of technologies or solutions can I apply to improve the situation for these users doing these tasks? […] once you identify these dimensions […] you can group existing designs along these different dimensions' (Researcher A, Nokia Research).

Futures are not explicitly described or espoused in these more orthodox methods but they are perhaps implied in the process of specifying multiple scenarios. This process does not specify a single technology, or a single version of a technology but rather 'dimensions' of design. Neither does this form of 'user-centred design' specify one particular means of performing a potential task. The 'tasks' identified for technological support can be quite diverse, from shopping and payment to telling bedtime stories. Anticipation is not an all-encompassing logic to R&D. The aim is often to support tasks in the world as we understand it now, rather than imagine anything radically different. It is interesting, however, that the language employed nevertheless remains in some way anticipatory:

> 'another thing that you can do with these kind of design space approach, is identify families of solutions, and then predict properties of one solution based on the properties of another solution' (Researcher A, Nokia Research)

A 'potential design space' is constructed, within which the various specified factors can be adjusted and 'gaps' can be identified and qualified in relation to potential needs. In response, 'families of solutions' provide multiple dimensions to potential future ways and means of using technologies. A range of dimensions are thus described and quantified that circumscribe potential. Therefore, even when they are not explicitly addressed, futures are inferred.

The subsequent work conducted following the forms of experimental and speculative research discussed here can be varied. For example, Researcher A reported that it was common to create several prototypes from the 'families of solutions' generated through user-centred techniques, whereas Researcher D reported that patents and 'intellectual property' was the typical outcome of their research, if further work was conducted, it took place in product divisions elsewhere in the world. Where these techniques for future orientation have agency is when they stabilise particular ways of thinking about future technology use as a form of knowledge that is subsequently taken as an assumption for further work.

Particular knowledges are the basis for stable means of future orientation, which both generate and derive from the techniques described here for anticipating futures. They are *anticipatory* knowledges that become assumed and form the foundation of (some) subsequent development strategies. Such knowledge is not simply given but is the practical achievement of techniques that articulate forms of potential (following: Anderson, 2007). There are of course limits to the expression of the imagination of future spaces, due to pragmatic design and development concerns or alternative strategies. The formulation of these forms of knowledge is nonetheless anticipatory; it operates through different kinds of logic to rationalise the conditions for addressing the future (Kinsley, 2011). The relative distance and specificity of the different kinds of future addressed can vary between near and far and sharp and vague but when those futures are used they are anchored in a form of knowledge. Spaces of potential are mapped out and concretised as assumptions, or knowledge, that form the point of departure for subsequent development strategies. These forms of anticipatory knowledge are accordingly the focus of the next section.

4. Anticipatory knowledge

There are many ways we describe a restless inclination towards the future and we should be careful not to elide the nuanced ways we use our vocabulary for future orientation. One risks being overly reductionist here but for the purposes of this discussion I will sketch some reasons for using the term 'anticipation' in this context. The techniques of ubicomp R&D, as described above, attempt to stabilise potential technology use such that devices and systems can be developed towards that use. A form of knowledge of future technology use is thus instantiated. The 'anticipatory knowledge' of future technology use, as ubiquitous computing, can be situated in relation to Anderson's studies of anticipatory 'action', 'logics' and 'practices' (2010b), in which he problematises how futures are 'known and rendered actionable… to thereafter be acted upon' (2010b, page 778). Where this work differs from Anderson (particularly 2007), is that the focus here is not on affective registers but spatial imagination and the anticipatory knowledges here are not embedded in governmental practices. This knowledge of future uses for ubicomp clearly has a basis in material action, as I have shown in section three. Therefore, in this section I use anticipatory knowledge as an analytical lens to further discuss the empirical account of techniques for anticipation and their limits presented in the previous section.

We can broadly understand 'anticipation' in relation to a nascent literature, in the social sciences, that charts the themes of anticipatory 'governance', knowledge' and 'logic' (Adey, 2009; Anderson, 2005, 2007, 2010b, 2010a, 2011; Ash, 2010; Barben et al., 2007; Dillon, 2007; Kraftl, 2008; Shields, 2008). Anderson (2010c, 2010b, 2010a, 2011) addresses anticipatory action principally in relation to undesirable circumstances, such as the mitigation of terrorism, disease pandemic and natural disaster and focuses on their affective registers. However, these conceptual tools can also be brought to bear on aspirational forms of future oriented action, in this case ubicomp R&D, and their associated forms of spatiality. I want to focus upon anticipatory 'knowledge' in this section.

The apparent apprehension and understanding of futures in particular contexts can be described as 'anticipatory knowledge' (Adam and Groves, 2007; Anderson, 2007). Such 'knowledges' have origins in divination and clairvoyance, and have been historically linked to mechanisms of governance (Adam and Groves, 2007, pages 2-6). We can also describe scientific practices of climate and weather modelling as anticipatory knowledges that have significant agency. People place confidence in the weather forecast, for example. Of course, such forms of anticipatory knowledge can be contested, as is the case with the debates on global climate change carried out in the media (see: de Goede and Randalls, 2009; Gavin et al., 2011; Grundmann, 2006; Weingart et al., 2000). The computing industry as such is largely built on a form of anticipatory knowledge of engineering progress that has been naturalised as 'Moore's Law'. In the late 1960s Gordon Moore, co-founder of the Intel Corporation, formulated a prediction that the complexity and performance of a computer chip at minimum cost would double every two years (Moore, 1965). It became a self-fulfilling prophecy, a goal subsequently met for many years thereafter. Furthermore, it was a knowledge simply assumed by Mark Weiser in the formulation of his vision of ubiquitous computing: ‘Central-processing-unit speeds reached a million instructions per second in 1986 and continue to double each year’ (Weiser, 1991, page 73).

Various, more widely adopted, forms of anticipatory knowledge are tied to forms of risk aversion, such as the risks of financial loss or of global climate change. Risk, as anticipatory knowledge, can thus be seen as calculable and collective, and as a means of organising capital (Ewald, 1991, pages 201-206). The intention of risk-related anticipatory knowledge is to identify and mitigate ‘exceptional’ circumstances that happen *to* us (cf. Anderson, 2010b; Dillon, 2007; O'Malley, 2000; Stengers and Zournazi, 2002). Many forms of anticipation are tied to a sense of ‘progress’, which can imply a singular narrative of the passage of time, a time that happens *to* us. This is, following Latour (1993, 1999, 2005), the assumption at the heart of ‘Modernity’[4], and, in relation to technology, a form of technological determinism (see: Wyatt, 2008).

I argue that the ubicomp R&D described here operates within a different sense of anticipation, that of the production of circumstances that happen *for* us. Some of the possible spaces of technological encounter rendered by R&D are pragmatic applications of emerging trends, many are more speculative and imaginary, as demonstrated in sections 3.1-3.2. This different sense of anticipation is evident in Weiser’s (1991) combination of fiction and ‘progress report’ for a future of ubiquitous computing (further useful discussion is made in Dourish and Bell, 2011, pages 9-22). Weiser provided details about the

[4] Following Latour (1993), the word ‘Modernity’ is used to constitute and perpetuate a quarrel where there are winners and losers, the ‘Moderns’ (following Latour, 1993) and others. ‘Modern’ is thereby doubly asymmetrical: it designates a break in the passage of time, and it designates a combat in which there are victors and vanquished’ (Latour, 1993, page 10). ‘Modernity’ is accordingly a rationale for regulating the understanding of the passage of time as linear.

practical ubicomp research underway but also concluded the article with the futuristic story of 'Sal'. While there are technical details of the proposed technologies in the article, it is through the imaginative framing of the future 'everyday life' of the character Sal that readers 'knew' what it would be like to live with ubicomp. The success of early visions for ubicomp was the establishing of an authoritative story, which stabilised a form of descriptive and technical narrative. This anticipatory knowledge of ubicomp facilitated the easy communication of a system of research themes (see in particular: Abowd and Mynatt, 2000), while also propagating an orientation towards a time in which such forms of technical encounter would be possible. As with 'Moore's Law', this is something of a self-perpetuating cycle. The forms of spatial imagination may remain stable but the accompanying anticipatory knowledges are refigured in terms of contemporary reinterpretations of the apparent 'goal' of ubicomp as new processor, sensor and networking technologies become possible and new user 'needs' are identified.

Researchers, like their knowledge, circulate. Many of the participants for the research discussed here have moved between several companies that conduct ubicomp research, both in Silicon Valley and further afield. It has been demonstrated elsewhere that the circulation of highly skilled labour both within Silicon Valley and globally to and from the region has substantial economic and intellectual effects in the entrepreneurial and productive potential of Silicon Valley (see: Saxenian, 1994, 2002) and globally (for example: Sassen, 1988). Movements of people, occasionally whole teams, and their associated expertise, are a means by which knowledges migrate that aids in the production of a common frame of reference around research programmes and, indeed, ubicomp itself. Physical movements of people and representational movements of words and images therefore constitute what

Latour (1999) calls a 'circulating reference', in this case of anticipatory knowledge.

The forms of anticipatory knowledge variously expressed in ubicomp R&D are expressed in resolutely spatial registers. They are understandings of technology use generated through the imagination, representation and simulation of possible practices and spaces. The techniques from which such knowledges often emerge, as described in section 3, externalise concepts and ideas as material artefacts and practices. A rich spatial imagination for worlds of ubiquitous computing has developed from future-oriented techniques for R&D and yet it rests in tension with the actuality of those very research practices. Furthermore, extant forms of ubicomp can be rather different from what is imagined. To conclude this article I address the somewhat paradoxical nature of anticipatory knowledges of ubicomp in relation to the associated forms of spatial imagination.

5. Conclusion

It is clear from the world around us, as Dourish and Bell (2011, pages 40-43) assert, that versions of ubiquitous computing have been realised that are alternative to those articulated by Weiser (1991) and others in the last 20 years. However, that does not mean we should ignore these forms of future orientation. These ways of addressing a near future have agency. By looking at the techniques employed, we can examine the ways in which particular orientations towards a future are produced. My aim in this article is not to elucidate the future orientation of the whole process of technology development, from research through product development and on to manufacture, but rather to uncover the specific forms of future orientation in R&D, which are often elided. Anticipation for ubicomp (in R&D) is a process, in this sense it is performative—an ongoing effort to address a future—but there are limits to the scope of that performance. The anticipatory knowledges that both facilitate and are formed by development techniques condition how ubiquitous computing is articulated. When articulated, anticipatory knowledges of ubiquitous computing are inherently spatial. I want to conclude, therefore, with some remarks about how we might reconcile these forms of anticipatory action to a form of spatial imagination.

The centrality of a 'proximate future… just around the corner or over the horizon' (Bell and Dourish, 2007, page 134) in Weiser's (1991) foundational vision of ubiquitous computing, and the manner in which it continues to live in the writings of contemporary researchers, continually places its achievements out of reach, while simultaneously eliding current technological practices. The distance of an anticipated future from the present connotes a relative activity of that future – both in one's ability to affect its production and the ways in which that representation of a future can perform. However, in the case of ubicomp, not only *was* the future of Weiser's vision proximate, it also remains so, as the referent object of anticipatory knowledge. The anticipated 'futures' of all subsequent renditions of ubiquitous computing remain anticipatory because they invoke that knowledge and are emergent from practises that take place in the present.

As a form of spatial imagination, the locus of the proximate future of ubicomp remains distantiated. Futures of ubiquitous computing are aspirational; they are not specifically taken as benchmarks or goals against which to measure 'progress'. Instead, futures in ubicomp R&D are often figured as a means to ascribe potential value to particular ventures, without necessarily specifying how that value will be derived. These proximate futures are often separate from the ways in which what is produced is addressed, measured and made manifest. What is produced, as prototypes, proofs of concept and imaginative representations, is measured and addressed as a present concern in terms of the potential value, they are what Anderson has called 'anticipatory epistemic objects' (2007, page 157). However, in contrast to Anderson's (ibid) analysis of nanotechnology, I argue that these 'anticipatory objects' of ubicomp do not principally operate in affective registers but rather in tension between imagination and practice.

We return then to the paradoxical nature of the anticipatory knowledge of ubicomp. The paradox has three parts: first, a general mythology of a proximate future of ubicomp remains proximate and un-actualised; second, specific knowledges are formed through the techniques for addressing futures that contextualise forms of potential technology use in the present; third, instrumental development techniques for developing technologies are also used that are not explicitly anticipatory. There is thus a peculiar tension between the future-oriented spatial imagination and the development practices of ubicomp. Future worlds of ubiquitous computing are imagined, and sometimes simulated, in ubicomp R&D but there are activities to develop ubicomp technologies, also for the future, that ignore those forms of imagination. Ubicomp is thus an important case study in the exploration of how popular forms of spatial imagination entangle with development techniques to produce settled means of addressing technological futures, as well as their limits.

Much of what is written about the potential for novel forms of technology, risks, hopes and warnings, is written in relation to the future projections presented by those with a vested interest in that technology and largely accepts these visions as normatively trustworthy and likely to be actually made. The reception of ubicomp has been no exception, we can find both enthusiastic (Galloway, 2004) and circumspect (Wood, 2008) readings of these visions. However, even those that are well thought through (for example: Kitchin and Dodge, 2011; using Greenfield, 2006) tend towards accepting visions of the future without critical reflection. I am not suggesting that there are not credible concerns about such visions of the future. However, these means of addressing the future orientation of technology research, and in particular ubicomp, construct the future projections of a world of ubicomp as 'black boxes' (Latour, 1999, pages 70,183-185) of apparently stable knowledge of the future. This abstraction elides the fact that the future projections are somehow produced, they have a basis in forms of action and in particular institutions or contexts, and we can study those states of affairs:

> 'Visions, images and beliefs cannot sharply be demarcated from knowledge… It is important to recognize how visions… interact and also how wide the gap separating [them] from practice can become before an uncontrollable backlash is provoked' (Nowotny et al., 2001, page 232).

With the increased involvement of 'publics' in the production of scientific and technological knowledge (see, for example: Paulos et al., 2008; Sui et al., 2012) and, within geography, a greater interest in emerging technologies—such as: urban technologies (Aurigi and De Cindio, 2008; Kitchin, 2011), genetics and biotechnologies (Davies, In Press; Shields, 2008) and nanotechnologies (Anderson, 2007; Macnaghten, 2010)—it has become increasingly important to recognise the agency of future visions that may underlie such work, and accordingly attend to how they are constructed.

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