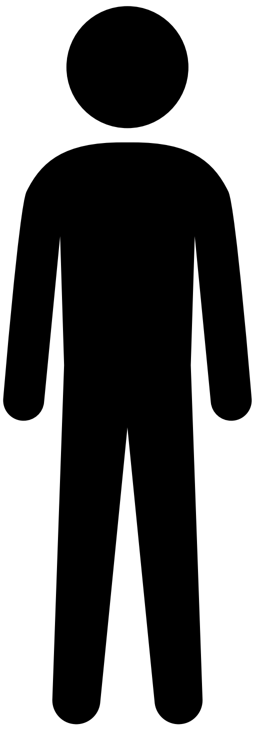

COMPUTERS FOR HUMANS: TANGIBLE COMPUTING AND AMBIENT MEDIA.

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Computers for Humans: Tangible Computing and Ambient Media.

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ABSTRACT

This dissertation concerns itself with the relationship between humans and computers. It grounds itself in Mark Weiser's prescient vision for the third paradigm of computing; ubiquitous computing. It will review the phenomenological philosophy underpinning ubiquitous computing, focussing on Paul Dourish's comprehensive study of the works of Edmund Husserl and Martin Heidegger. We will identify core characteristics of ubiquitous computing that can be used to assess the development of tangible computing and ambient media from the 1990's onwards, with a focus on the work of MIT's Media Laboratory Tangible Media Group. We will address the concept of affordances, as outlined by James Gibson and further developed in the field of human interaction by Donald Norman and William Gaver. We will progress to Norman's theories on emotional design and the affect of aesthetics on usability. The aim of this dissertation is to assess the progression of calm computing principles and the notion of embodied virtuality, with a goal to outline new characteristics for ubiquitous computing. New characteristics that address the maturation of the technologies that surround ubiquitous computing.

CONTENTS

INTRODUCTION

The artefacts of Today's modern computing technology are almost unrecognisable as descendants of their primitive predecessors. The computer entered the commercial market as a static behemoth that resided almost exclusively in the cupboards, back rooms and basements of corporate and governmental offices. It had no single operator; its time and resources were shared between multiple users. This was the era of the mainframe computer.

The first major paradigm shift occurred in the 1980's, as the mainframe escaped its dimly-lit confines and fixed itself firmly and securely to the desktops of individual employees and hobbyists. The computer-to-human relationship was a one-to-one affair, and so began the age of the personal computer. As the personal computer rose to prominence as its numbers and use grew, it did so surrounded by somewhat of an 'arcane aura' (Weiser, 1991, p.94). It spoke a different language, indecipherable to everyday folk. It operated outside of the confines of everyday life, accessible only whilst seated before it at a desk. Its form and the mode by which we interacted with it were changing very little. It was yet to undergo anything akin to a metamorphosis; still a far cry from the techno-utopian futures that had been promised by science fiction. In an 'age of beige boxes' (Dourish, 2001, p.27) something more than a newly designed cuboid was necessary to change the nature of computing as we knew it. Something had to happen at a fundamental level, a re-imagining of our future and the role that computers played in it.

Mark Weiser witnessed the rise of the personal computer whilst head of the Computer Science Lab (CSL) at Xerox's Palo Alto Research Centre (PARC) in California. The interdisciplinarity of PARC exposed Weiser to the ideas, thoughts and insights of sociologists, psychologists, and anthropologists, which ultimately inspired him and his colleagues 'to take a radical look at what computing and networking ought to be like' (Weiser, 1988). Weiser envisioned a type of computing that was ubiquitous. It was the inverse of its mainframe predecessor; providing each user with many devices, in the tens if not hundreds. Ubiquitous computing (ubicomp) would see computers present at each and every level of our day-to-day lives, 'imbedded in walls, chairs, clothing, light switches, cars - in everything' (Weiser & Brown, 1996, p.4). Ubicomp is defined not just by the abundance of computers, but also by their persistent and total connectedness, and the underlying infrastructures that facilitate such a thing.

PARC stayed true to its philosophy of "Build what you use, and use what you build" (Want, 2010, p.4) and, under the guidance of Weiser, embarked on a project to realise ubicomp. Given the high cost and limited capabilities of existing technologies, it was — slightly ironically — ubiquitousness on a small-scale. However, it provided the CSL team with the necessary environment in which to explore the requirements, effects, and emergent traits of ubicomp.

Weiser's vision and the work being undertaken at PARC was not going unnoticed in the wider world. Throughout the 90s ubicomp influenced a number of projects that explored the possibilities of this kind of computing. Projects that took place in both corporate and academic research labs, run by the likes of IBM and Hewlett Packard, MIT and Georgia Tech. With each new project came a new term that more succinctly conveyed the nature of its unique brand of ubiquitous computing, whether for marketing reasons or otherwise. Such terms include pervasive, tangible, and physical, some of which I will return to in the coming chapters.

The fundamental characteristics of ubiquitous computing that Weiser himself — explicitly and implicitly — outlined in 'The Computer for the 21st Century' and his publishings thereafter will form the basis of this dissertation. Characteristics which addressed aspects of the current paradigm of personal computing and set the precedent for technologies that would more appropriately fit themselves to the real-world and capitalise on our familiarity with it. The refinement of these characteristics in the new fields that emerged in the wake of ubicomp will build on this base, conducted through the exploration and analysis of the archetypal projects from each area.

A most critical aspect of Weiser's vision for a ubiquitous computing, one which can clearly be seen in the projects that it has both influenced and given rise to, is the concept of embodiment. It's first mentioned in the context of 'embodied virtuality' (Weiser, 1991, p.98) as the notion of 'drawing computers from their electronic shells. The "virtuality" of computer-readable data all the different ways in which it can be altered, processed and analyzed is brought into the physical world' (Weiser, 1991, p.98). It's the philosophical, psychological, and sociological underpinning of the ubiquitous computing paradigm, and will be the topic of the first chapter of this dissertation. It will call upon the work of Paul Dourish regarding embodied interaction. Focusing on his analysis of the phenomenological traditions founded by Edmund Husserl and further developed by Martin Heidegger.

The second chapter will review examples of projects which directly employ this notion of embodied virtuality. Primarily the work development tangible computing and the work of the MIT Media Laboratory's Tangible Media Group in their effort to join the worlds of atoms and bits. Donald Norman's work on affordances, usability and emotional design will also feature heavily.

If the artefacts of Today's modern technological era were to multiply at the rate which Weiser (1991) envisioned for ubiquitous computing, we'd be at the mercy of a myriad of bleeping, chirping, and rumbling gizmos and gadgets, each vying for our undivided attention — even more so than we are already. Weiser & Brown (1996) warned that 'if computers are everywhere they better stay out of the way' (Weiser & Brown, 1996, p.7). Ubiquitous computing will have to be inherently calm. Efforts to make the way in which computers display information more natural, ambient, and calming will be the focus of my third chapter.

In the final chapter, I will review the current state and direction of ubiquitous computing, contextualising it within the larger technological landscape. Giving reference to the likes of Bruce Sterling with the aim of identifying new characteristics that have emerged from its maturation in the last two decades.

EMBODIMENT

The notion of embodiment is the foundational underpinning of ubiquitous computing, it rudimentarily concerns itself with the fact that 'humans are of and in the everyday world' (Weiser, 1993, p.76).

At around the same time that ubiquitous computing was finding its feet, ideas and technologies surrounding the starkly contrasted approach of virtual reality were also building up steam. Virtual reality proposes a model that seeks to inhabit the user in a computer-generated world. It detaches our consciousness from its fleshy confines and beams it into the fictional environment it has created for us. A three-dimensional space designed to resemble the real world — often complete with naive physics, occlusion, and even proprioception — as to exploit our familiarity with the nature and structure of it. This use of the real world as a metaphor for interaction is distinctly different to using at as medium for interaction (Dourish, 2001, p.101). Even in the most immersive virtual reality environments, 'users are disconnected observers of a world they do not inhabit directly' (Dourish, 2001, p.102). Just as '…a disembodied brain could not experience the world in the same way we do' (Dourish, 2001, p.18), nor can our disconnected consciousness inhabit a virtual reality, 'because our experience of the world is intimately tied to the ways in which we act in it' (Dourish, 2001, p.18).

> There is no homunculus sitting inside our heads, staring out at the world through our eyes, enacting some pan of action by manipulating our hands, and checking carefully to make sure that we don't overshoot when reaching for the coffee cup. We inhabit our bodies and they in turn inhabit the world, with seamless connections back and forth' (Dourish, 2001, p.102).

Cartesian dualism separates the mind and body as two distinctly different entities — to 'think' and to 'be' are two disparate sets of phenomena (Dourish, 2001, p.107). It's clear that virtual reality adheres to this notion, but the same cannot be said for ubiquitous computing. Weiser (1991) alludes to the contrasting stance of ubiquitous computing with his use of the phrase 'embodied virtuality' (Weiser, 1991, p.98). Rather than the user entering the computer's domain, the computer is lured from its electronic shell into the real world — 'The site of interaction is the world of the user, not that of the system' (Dourish, 2001, p.38). Ubiquitous computing is more aligned with the philosophy of the phenomenological tradition.

Dourish (2001) states that phenomenology was founded by Edmund Husserl as an exploration of human experience and perception. Husserl was attempting to address the abstract and idealised approach of scientists and mathematicians of the era. Such methodologies distanced themselves and their work from everyday practical concerns, and in doing so, the live experience of people acting in the world (Dourish, 2001, p.104). Husserl 'envisioned a science that was firmly grounded on the phenomena of experience, which in turn meant developing the philosophy of experience as a rigorous science' (Dourish, Page 105, Where the Action Is).

Husserl proposed phenomenology as a method for examining the nature of intentionality; the way mental states could refer to elements of external reality. It aims to uncover the relationship between the objects of consciousness and our mental experiences of them — how 'noema' relate to 'noesis'. Phenomenologists must not assume an objects existence based on its perception — for this is its objective, to understand how in perceiving something we assume its existence (Dourish, 2001, p.105).

Husserl states that there is a parallelism between the objects of perception and the acts of perception. For example, when I see a rabbit, I have not only to recognise that what I'm seeing is a rabbit, but also that what I'm doing is seeing it (as opposed to imagining it or remembering it). Husserl saw that mental acts could become phenomena of experience as one referred and reflected on them (Dourish, 2001, p.105). When an individual recognises that what they are seeing is a rabbit they move from the world of everyday affairs, beyond the sensory stimuli, and into the life-world. 'The life-world [or lebenswelt] is the intersubjective, mundane world of background understandings and experiences of the world' (Dourish, 2001, p.105-106).

Martin Heidegger was a student of Husserl and used his work on phenomenology as a starting point as he too sought to uncover to intentionality of experience. Heidegger, however, saw his predecessor's focus on mental phenomena occurring in isolation from the body as fundamentally flawed. He reversed Descartes' dictum 'cogito ergo sum' to propose that 'clearly one needed to be in order to think' (Dourish, 2001, p.107). To Heidegger, our being in the world and our experience of it shapes the way we understand it 'because our understanding of the world is essentially an understanding of how we are in it' (Dourish, 2001, p.107). Descartes saw that the mind was the seat of reason and meaning — we observe the world and give it meaning by relating it to abstract understandings of (an idealised) reality. Heidegger situated the meaningfulness of everyday experience, not in the head, but in the world. 'Heidegger asked, "How does the world reveal itself to us through our encounters with it?"' (Dourish, 2001, p.107).

'Meaning inheres in the world as we find it' (Dourish, 2001, p.108) — the things we do, practically, and the ways in which we act and how this action is accommodated in the world is what makes the world meaningful to us. At the heart of this thinking is Heidegger's concept of Dasein, the essence of being human and how 'being' is inseparable from the world in which it occurs (Dourish, 2001, p.108). Dasein's orientation toward the world is a fundamentally practical one, but action is not just carried out on the world, but also through it. Heidegger's theory regarding

> … consider the mouse connected to my computer. Much of the time, I act through the mouse; the mouse is an extension of my hand… The mouse is ... ready-to-hand. Sometimes, however, such as when I reach the edge of the mousepad … my orientation toward the mouse changes. Now, I become conscious of the mouse mediating my action ... The mouse becomes the object of my attention ... When I act on it in this way, being mindful of it as an object of my activity, the mouse is present at hand. (Dourish, 2001)

The ease with which a tool or piece of equipment can become ready-at-hand is testament to how well it is designed. The more readily a device, computational or otherwise, fades from consciousness to allow its user to concentrate on the task they are currently undertaking, the better. If the user is focused on the object itself instead of their end goal, say to adjust it due to discomfort, it becomes present-at-hand in an abrupt and dissatisfactory manner, far from conducive to a good piece of equipment. In order to act through technology with any efficiency, an object '… in its readiness-to-hand, must, as it were, withdraw in order be ready-to-hand quite authentically' (Heidegger, 1927 cited in Dourish, 2001).

EMBODIED VIRTUALITY

The earliest artefacts of ubiquitous computing, developed by Weiser and his colleagues at the Computer Science Lab in Xerox's PARC, came in the form of tabs, pads, and boards. Each was designed to suit a relative scale at which humans interacted with the world; the inch, foot, and the yard. As a suite of devices they were analogous to the post-it notes, sheets of paper and whiteboards that already inhabited the working environment. Each offered many of the same affordances as its 'analog' predecessor; augmented with the digital functionality facilitated by constant network connection, amongst the usual advantages. They succeeded in demonstrating the distributed nature of ubiquitous computing, but absent was Weiser's notion of 'embodied virtuality' (Weiser, 1991, p.98). Tabs, pads, and boards merely provided windows from the physical world into that of the virtual. Windows that were populated by the familiar icons, menus, and pointing devices of the graphical user interface (GUI) model — something it had in common with the personal computing paradigm it sought to supersede. The context in which computing took place was now changing, but the interaction with the computers remaining much the same. It was certainly a step in the right direction, but there was work to be done.

Materialising Marbles

The systems involved in voicemail are still to this day a source of anger and annoyance for many. It's often quicker and easier to immediately return someone's phone call than it is to navigate the archaic systems in which their message has been stored. Visual voicemail removed much of the pain of interfacing with these systems by providing an alternate mode of interaction. Rather than primitive vocalised menus and touch-tone inputs we were granted the luxury of a GUI. But despite its superior user experience it's yet to be adopted by all mobile phone operators. Visual voicemail provides a graphical visualisation of the system, the messages within it and the operations that can functions that are available to the user.

Long before the concept of visual voicemail, or even mobile phones, Durrell Bishop contemplated a different type of interaction for the common telephone answering machine. Whilst studying his MA in Interaction Design at the Royal College of Art in London he prototyped the 'Marble Answering Machine' (Smith, Page 60, The Hand that Rocks the Cradle). Each message that was recorded on the machine was mapped to a physical marble that was released by a mechanism and rolled into a linear trough. The presence of indentations on the answering machine and peripherals that surround it afford placing the marble within. The location of these indentations corresponds to their function, for example, placing a marble atop the phone would dial the phone number of the individual who left the message. Messages are deleted when the marble is returned to the machine.

The function of the marble extends beyond its use within the technical system. The marble itself contains no data; it is simply a token representation of the message stored within the digital system. The marble is, as well as being the physical instantiation of a digital voice regarding, still just a marble, and so it has the same potential for activity as any other. As Bishop's (2011) demonstration shows, it can kept in a dish for the desired recipient, have a note attached to it, and be hidden away in a drawer for safe keeping.

The work of designers and artists such as Durrell Bishop and Natalie Jeremijenko certainly hadn't gone unnoticed in the developing area of ubiquitous computing research. Their focus on making the immaterial, material, and presenting alternative modes of interaction and informational displays is visible in the tangible computing projects that appeared in the 1990's.

Tangible Bits

> We live between two realms: our physical environment and cyberspace. Despite our dual citizenship, the absence of seamless couplings between these parallel existences leaves a great divide between the worlds of bits and atoms. At the present, we are torn between these parallel but disjoint spaces … "Tangible Bits" is an attempt to bridge the gap between cyberspace and the physical environment by making digital information (bits) tangible. (Ishii & Ullmer, 1997, p.1-2)

'Graspable user interfaces' (Fitzmaurice, Ishii & Buxton, 1995, p.442) were amongst the first tangible computing experiments. Physical objects, referred to as bricks, sit atop a horizontal display and are coupled with a virtual element which is visible on the screen. The brick can be used to manipulate its virtual partner, the actions it permits relate to, but not dependent on, the affordances of both the physical artefact and the virtual object to which it is coupled. The introduction of a physical, graspable input mechanism to user interfaces has numerous advantages, from two-handed interaction to multi-person collaborative use (Fitzmaurice, Ishii & Buxton, 1995, p.442-443). The majority of which are concerned with incorporating and enhancing our skills and abilities as humans that occupy the everyday world.

Affordance

The term 'affordance' emerged from the ecological psychology of J. J. Gibson. Gibson (1986) defined the affordances of an environment as '…what it offers the animal, what it provides or furnishes, either for good or ill' (Gibson, 1986, p.127). An object affords certain actions to a entity based on its physicality and on the capabilities of the entity. Norman (1988) introduced the concept of affordances to the design of everyday things as a means by which users might deduce — without complex cognitive process — the function of an object from its form:

> …the term affordance refers to the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used. A chair affords support and, therefore, affords sitting … Knobs are for turning. Slots are for inserting things into. Balls are for throwing or bouncing. When affordances are taken advantage of, the user knows what to do just by looking: no picture, label, or instruction is required. (Norman, 1988, p.9)

Much ambiguity arose around the definition of affordance when Norman first introduced the concept to the field of design. Norman (Norman, 2007, p.68) sees the visibility of an affordance as being a critical factor — if an affordance goes unnoticed or, in the words of Gaver (Gaver, 1991, p.80), is hidden, then it is worthless (in its current form and context, at least). However, McGrenere and Ho (McGrenere & Ho, 2000, p.1) suggest that Gibson intended an affordance to mean a opportunity for action that existed within an environment, regardless of an individual's ability to perceive it. This led to Norman (1998) outlining the difference between perceived affordances — core to his notions of usability — and real affordances. 'Perceived affordances are often more about convention than reality' (Norman, 1998, p.124) and their perception is dependent on an individual's culture, social settings, and existing knowledge.

Gaver (1991), in suggesting affordances as a tool for user-centric analysis of technologies, proposes that affordances 'are not passively perceived, but explored' (Gaver, 1991, p.82). Though this is of more relevance to complex systems than it is to everyday things, Norman's (1988) principles of visibility, feedback, and forcing functions go a long way to providing designers with the tools to develop tangible computing systems that reward, rather than punish, their users for exploring them and their capabilities.

Perceived affordances are a key feature in the toolkit of tangible computing. This isn't to say that affordances don't exist in the field of digital interaction, but perhaps that the societal and cultural barriers of previous knowledge and familiarity are much lower for physical objects than visual interface elements. Everyone occupies the real world, a growing number occupy the digital, but not all.

Dourish (2001, p.50-51) draws attention to potential difficulties which may arise due to the distributed nature of tangible computing: not only are there multiple points at which a user can act, but are also many actions that can performed at any one time, in parallel. As Dourish (2001, p.52) acknowledges when presenting these issues; sequentially designed affordances can help to guide a user through a multi-step physical process. Gaver (1991) explains the concept of sequential affordances with the example of a pivoting door handle:

> …[it] may appear to afford grasping, but passive observation will probably not indicate the affordance of turning it or using it to open the door. However, once grasped, a random or exploratory press downwards will convey tactile information revealing the affordance of turning the handle. When the handle is fully turned, the new configuration is one from which pulling is natural. The results of a pull will indicate whether the door affords opening or not. (Gaver, 1991, p.81)

Losing Touch

We shaped the tools that enabled us to manipulate the world around us and in turn those tools shaped us. Gradually, over time, our hands began to evolve in order to better utilise them (Reardon, 2013). To have it put succinctly; 'Man is "man the tool maker"' (Sterling, 2005, p.56). But convergent design of late has resulted in a plethora of exquisitely designed rectangles which, though mobile, functional, and powerful (in more ways than one) reduce our level of interaction to not much more than pushing around 'Pictures Under Glass' (Victor, 2011).

Norman (Page 80, Emotional Design) reflects on the interpolation of physical processes, actions, and activities into the virtual or digital world as having eliminated 'one of the great delights of real interaction: the delight that comes from touching, feeling, and moving real physical objects' (Page 80, Emotional Design).

> Far too many high-technology creations have moved from real physical controls and products to ones that reside on computer screens, to be operated by touching the screen or manipulating a mouse. All the pleasure of manipulating a physical object is gone and, with it, a sense of control. Physical feel matters. (Page 79, Emotional Design)

Tangible computing systems not only capitalise on our familiarity with the world in which we reside, but also the finesse and dexterity with which we can manipulate it and the artefacts; tools and equipment, that it offers and that we have crafted from it.

An Aesthetic Conundrum

Emotion, despite its often negative connotation, is an incredibly important part of who we are as humans, 'affecting how you feel, how you behave, and how you think' (Norman, 2004, p.10). Norman (2004) identifies the three levels of the brain which are attributed to control our emotional state:

> …the automatic, prewired layer, called the visceral level; the part that contains the brain processes that control everyday behavior, known as the behavioral level; and the contemplative part of the brain, or the reflective level. (Norman, 2004, p.21)

These three levels of the brain are (in an act of gross simplification and reductionism) associated with appearance, usability, and personal satisfaction in regards to physical objects (Norman, 2004, p.39).

The appearance of objects, attractive or otherwise, affects us on a primitive, visceral level. Aesthetically superior design, which satisfies the prewired conditions of the brain, gives rise to positive affect – pretty things literally make us feel good. Feeling good does wonders for the brain; 'positive affect … fosters clear-headed, well-organized, open-minded, flexible problem solving and thinking' (Isen, 2001, p.83). So, 'good' design not only makes us feel happy, it also helps to think more creatively. When a device doesn't operate as expected – 'it fails to produce the desired result' (Norman, 2004, p.19) – a positive, happy state of mind enables the user to look for alternate solutions.

Aesthetically good design cannot be relied on entirely, it's simply not practical to think that something could get by solely on its looks. Aesthetics should be seen to compliment usability, perhaps in some ways; to make up for the short-comings, but primarily it is a complimentary pairing, they are not mutually exclusive and the power of each should be harnessed in all areas of design.

Visually engaging design isn't all rainbows and butterflies though, it's somewhat of a double-edged sword, best illustrated by Weiser's (1994) question; 'should computer interfaces be attractive at all? Attractiveness is the opposite of invisible' (Weiser, 1994, p.7). Attractive design is in conflict with Weiser's notion of an 'invisible' computing. A nice object distracts your attention in order for you to appreciate its beauty; it becomes present-at-hand. In doing so you pay more attention to the tool at hand than the activity you are acting through it to achieve. This could therefore effect your ability to use it.

CALM COMPUTING

> The most potentially interesting, challenging, and profound change implied by the ubiquitous computing era is a focus on (Weiser & Brown, 1996, p.7).

The goal of calm computing is to counter-act the information overload that comes hand-in-hand with the increased presence of computers in our everyday lives. Calmness mustn't simply be a property of the information displays themselves, but they should instil a sense of calm in users too. It's not as straight-forward as reducing the amount of data that is presented to users, nor pacifying the means by which it is brought to their attention. Phones shouldn't stop ringing, notifications from pushing, and appliances from beeping — though that certainly has something to do with it. In the advent of ubiquitous computing our environment becomes our primary computational interface. The key to calmness is rooted in the design of computers that are able to drift, willfully, from the centre of our attention to the far reaches of our periphery (Weiser & Brown, 1996, p.8).

Attention Theory

As we go about our everyday lives we direct our attention towards external sensory stimuli and internal cognitive processes. Given the amount of information that we are exposed to, be that from our surrounding environment or the thoughts and memories that occupy our minds, it's a wonder we can make sense of the world at all. In order to do so we must selectively allocate attention to those sources of input. There are two major models which suggest how it is that we do this, one is a model of selective attention and the other of divided attention (Bakker, Hoven & Eggen, 2010, p.72).

Selective Attention

Selective attention is just as it sounds; we simply select one of the multiple incoming streams of sensory and cognitive activity and attune to it. In doing so, we actively block out the secondary sources of stimuli. It's a model of filtration. The main question for psychologists of the 1950's and 60's was how this selection happened, when informational streams were filtered and whether content from unattended streams was actually perceived, and if so, at what level (Bakker, Hoven & Eggen, 2010, p.73).

Experiments around the matter were conducted by the likes of Cherry (1953) and Moray (1959) and showed that if secondary streams contained words that were important to the individual (their name for example), then they are consciously perceived. Thus it follows that all streams are to some degree perceived and filtration happens late in the operational stack.

The currently accepted theory of selection is Treisman's (1964) attenuation theory. Treisman found that if the subject matter of secondary streams was similar to that of the primary one, the one being attended to, then the secondary will consciously or unconsciously influence the one being attended to. This is an example of the process called priming; the activation of detector units within the brain that lower the threshold for identifying information within a channel that an individual is not directly attuned to (Bakker, Hoven & Eggen, 2010, p.74).

Distributed Attention

Distributed attention concerns our ability to multi-task; to divide our limited mental capacity over different activities. Different activities require differing amounts of mental effort. We can perform multiple tasks that require little attention in parallel and fewer task that require lots of attention. Our level of experience in and the difficulty of specific tasks debates how much attention they require. We can expend attentional resources on any of the potential activities that arise from informational input. The manner in which we distribute those resources is down to our own intentions, but is also influenced by external phenomena, such as someone speaking our name, or salient sensory stimuli such as a loud noise distracting our attention. The more engrossed we become in one specific activity, the less likely we are to pay attention to other informational streams (Bakker, Hoven & Eggen, 2010, p.75).

Centre and Periphery

These terms are analogous to those used in the context of vision; if I'm focusing on one activity, it is at the centre of my attention and all other potentials for activity lie in the periphery, at the external boundary of my attention. Potential activities can reside in the periphery, where they require little attentional resources. When an activity becomes relevant, it shifts from the periphery into the centre where it can intentionally be performed (Bakker, Hoven & Eggen, 2010, p.77-78).

It's the nature of informational displays that facilitate this transition that is of primary importance to calm computing. Sudden, loud, and unpleasant sounds can achieve this change in the focus of attention, but not in a manner that could be considered calm. Treisman's notion of priming, discussed above, is certainly of interest for this purpose, but it's safe to say that this is still a young field, and it's hard to identify with any certainty, the types of informational displays that will fit this need in every context. A practical process of trial and error, and iterative design is a good way to go (Bakker, Hoven & Eggen, 2010, p.78-79).

Ambient Media

The majority of electronic devices blink, beep, and vibrate in an attempt to communicate with us, but succeed only in signaling at the very best. So how might the myriad of devices that make up our technological lives bridge the divide and take up residence in our periphery? Norman (2007, p.58-59) suggests that designers should take cues from those phenomena that already do; 'natural signals inform without annoyance, providing natural, nonintrusive, nonirritating, continuous awareness of the events around us' (Norman, 2007, p.58-59). Natural environmental phenomena fall easiest into our periphery as they are those which we have become accustomed to, both individually and evolutionarily. They provide us with a rich tool set to fit system feedback and output to our sophisticated array of senses.

As an example, MIT's Tangible Media Group developed an 'ambientROOM' concept which utilised a number of ambient media such as 'such as light, sound, airflow, and water movement' (Ishii & Ullmer, 1997, p.1) which were directly inspired by 'natural phenomena such as wind, sunlight, or the sounds of a rainforest' (Ishii et al., 1998, p.1). Ishii et al. (1998, p.1) interpret the centre and periphery of attention as 'foreground' and 'background' of awareness — multiple sources of information can be monitored concurrently in the background whilst we are concentrating on the primary source in the foreground.

One feature of the ambientROOM was the use of rain to subtly convey the number of hits a website was receiving, by manifesting each page view as the sound of a raindrop. The website activity could be monitored peripherally as the soundscape phased from trickles to torrents and back throughout the day. Corresponding to specific events, be that a feature on a blog or perhaps even a technical fault with the web server (Ishii & Ullmer, 1997, p.6). It was a move to a more natural display of information, but despite this sound, natural or otherwise, can be a difficult sensory stimulus to ignore. It requires a great deal of finesse on the part of the designer to ensure that it avoids entering the realms of distraction and annoyance. 'The individual, not the environment, must be in charge of moving things from center to periphery and back' (Weiser & Brown, 1996, p.13) for it must 'offer, but not demand' (Weiser & Brown, 1996, p.14). The MIT Tangible Media Group observed their use of raindrops crossing this divide whilst testing their ambientROOM and opted instead to employ the use of light, a medium perhaps more suited to ambient conveyance. The group 'built a thin water tank outfitted with a solenoid-driven float … With each pull, the float creates a ripple on the surface of water. Light projected onto the water tank from above casts a subtle but poetic image of ripples on the ceiling of the room' (Ishii & Ullmer, 1997, p.6). It was much more successful than its audible predecessor, testimony to the trickiness of (peripheral) sonic displays of information.

Perhaps the earliest and most elegant example of calm technology is Natalie Jeremijenko's 'Live Wire'. Created whilst an artist-in-residence at Xerox's PARC in 1995; the installation consists of a piece of plastic string connected to an electric motor. The motor flutters with each bit of information that passes along an Ethernet cable. It resides in the corner of an unused corridor, visible and audible through the open doors of nearby offices, not enough to be a distraction, but sufficient as to provide an insight into the busyness of the network. The more data being transferred on the network the faster the string spins and whirrs (Weiser & Brown, 1996, p.15).

CONCLUSION

Computers are renowned for being, disruptive, consuming, and difficult to use.

But it's clear from this research that, under the guise of ubiquitous computing, developments in tangible computing and ambient media are seeking to rectify that. The personal computer — and us with it — is being gently, but convincingly lured from the desk and into the real world; our real world. A world that will soon be filled with ambient information and computers that alert us through peripheral cues rather than salient alarms.

However, the fact that I type this whilst sat at a desk upon which there resides no single artefact of tangible computing alludes to an issue. There is no doubt about it; tangible computing is hindered by its inherent physicality.

The development of software-based interfaces — GUIs, augmented and virtual reality — are at a distinct advantage in that aspects of the system can be modified in real-time, with each change being monitored by version control systems, the likes of Git. Tangible computing systems however, don't yet have ability to drastically alter the material properties of an object at the drop of a hat. So, for now, artefacts of tangible computing ought to be more SPIME-like. With the rise of rapid prototyping through the ever-reducing cost of micro-controllers, 3D printers, and their associated materials and peripherals, will come about new possibilities for tangible computing. From both the hobbyist's study and the industrial designers workshop.

Following on from ideas of rapid prototyping is the issue of sustainability. It should be a primary concern of any industry, but especially ones burning through plastics and polymers at a rate of knots. Future technologies surrounding ubiquitous computing, tangible computing, and ambient media ought to be sustainable.

The balance between the usability and aesthetic appeal of technological artefacts is always difficult to find, but as we've seen; they are not as dissimilar as one might first think. Usability and attractive designs both have a place in ubiquitous computing's future, specifically in the role of enticing the general public rather than technologists and early-adopters.

The tasks and contexts for which tangible computing systems are developed often seem quite alien to the everyday person. Hybrid systems are needed, that push the balance from the tangible, a little further back to the virtual in order to create general purpose tangible computing peripherals which rely primarily on software applications to manipulate their functions and capabilities.

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