

The Changing Face of Human-Computer Interaction in the Age of Ubiquitous Computing

Yvonne Rogers
Pervasive Interaction Lab,
Open University, Milton Keynes,
MK7 6AA, UK
y.rogers@open.ac.uk

Abstract. HCI is reinventing itself. No longer only about being user-centered, it has set its sights on pastures new, embracing a much broader and far-reaching set of interests. From emotional, eco-friendly, embodied experiences to context, constructivism and culture, HCI research is changing apace: from what it looks at, the lenses it uses and what it has to offer. Part of this is as a reaction to what is happening in the world; ubiquitous technologies are proliferating and transforming how we live our lives. We are becoming more connected and more dependent on technology. The home, the crèche, outdoors, public places and even the human body are now being experimented with as potential places to embed computational devices, even to the extent of invading previously private and taboo aspects of our lives. In this paper, I examine the diversity of lifestyle and technological transformations in our midst and outline some ‘difficult’ questions these raise together with alternative directions for HCI research and practice.

Keywords: Human–Computer Interaction, Ubiquitous Computing, Pervasive Technology, Methods, Human Values, Research Agenda, Future Technologies

1 Introduction

Our world is becoming suffused with technologies that have the potential to profoundly change how we live. Computers now intrude on our lives as well as disappear into the world around us; they monitor as well as guide us; and they coerce as well as aid us. They are increasingly becoming part of our environments, in public spaces such as airports, garages, and shopping malls as well as in the private spaces of our homes and offices. As part of this transformation, our minds are extending more into the world. It is commonplace for people to use online calendars to remind them to send a birthday card to a friend and Google information on their mobile during ongoing conversations at dinner parties. People who own an iPhone are noticing how it is taking over more and more brain functions, increasingly replacing and augmenting parts of their memory, such as storing addresses and numbers that once would have required cognitive effort to recall [1]. Car Sat-Nav (GPS) systems have

also replaced map reading; drivers can now follow simple instructions reducing the cognitive effort that was needed to work out the best route.

At the same time affordable computing devices, especially mobile phones, have become more accessible across the globe. More people than ever are using a computing device of one form or other, be they a retiree in Austria, a schoolchild in Africa or a farmer in Ecuador. The way children learn is also changing as more and more technologies are assimilated into their lives [2]. For example, how it happens (e.g., taking part in a discussion with people from all over the world on Second Life) and when it happens (e.g. listening to a podcast about pollution while cycling home) is diversifying. The number of elderly people is increasing as a proportion of the total population. Those growing old in the next ten years will have become accustomed to using computers and mobile phones in their work and leisure. Hence, the need to design computer applications for old people who have not used email or the Web will no longer be a major concern but designing social network sites, creative tools, etc., for healthy, active seventy year olds will.

Technological developments, therefore, are not only altering the way we grow up and grow old, but pervading almost every aspect of our lives, from shopping to medicine, increasing our reliance on them. We are spending more time, and devoting more effort to being in touch with each other than ever before. Our unbridled desire to keep in touch is equaled by our desire to capture more information about our lives and our doings than ever before. What it means to record, why we record and what we do with the collected materials is also changing. This is happening not just at a personal level, but also at the level of government, institutions and agencies.

What do all these changes mean for the field of Human-Computer Interaction and those who research ‘user experiences’ and practice ‘UX design’? In an effort to keep abreast, HCI research is also changing apace: from what it looks at, the lenses it uses and what it has to offer. No longer only about being user-centered, it has set its sights on pastures new, embracing a much broader and far-reaching set of interests. From emotional, eco-friendly, embodied experiences to context, constructivism and culture. Its mission, purpose, goals and methodologies, that were well established in the 80s, have all greatly expanded to the point that “HCI is now effectively a boundless domain” [3] and is “bursting at the seams” [4]. Everything is in a state of flux: the theory driving the research is changing, a flurry of new concepts are emerging, the domains and type of users being studied are diversifying, many of the ways of doing design are new and much of what is being designed is significantly different. What was originally a confined problem space with a clear focus that adopted a small set of methods to tackle it – that of designing computer systems to make them more easy and efficient to use by a single user – is now turning into a more diffuse problem space with a less clear purpose as to what to study, what to design for and which methods to use.

Much is to be gained from this rapid expansion. A danger, however, is that the field may spiral out of control [5] and lose its identity [6]. The trivial and the serious may sit side-by-side and where everything and anything is potentially a topic for HCI. While ‘living without parental controls’ [7] can be liberating and inevitable in a rapidly transforming society, the questions HCI researchers ask, the purpose of their endeavors and the motivation behind them need continued scrutiny, debate and reflection, if their outputs are to continue to be of relevance and value to society. Part

of this will entail setting new agendas; determining what to throw out and what new topics and concerns to focus on. Even its very core – prescribing usability, i.e., how to design ‘easy-to-use’ tools – needs rethinking since *using* technology in its various manifestations, is second nature to most people and hence unproblematic. The classic interface horror stories, such as the flashing VCR, are being superseded by more pressing matters that face society in the 21st century, such as how pervasive technologies are intruding and extending our physical bodies, cognitive minds and social lives. These are the concerns that the HCI community needs to wrestle with; explicating what it means to be human in an age of ubiquitous computing [8].

In this paper, I explore some new directions for HCI research and practice. I consider how the HCI community of researchers, practitioners and designers can play a new role in shaping society’s evolving relationships with computer technologies. I argue that a quite different mindset is needed than the ‘easy-to-use’ and ‘comfortable living’ philosophies that have motivated much HCI and ubiquitous computing research. A new research agenda is proposed which sets out how to augment everyday activities using the portability, pervasiveness and computational power of ubiquitous infrastructures and mobile devices [8, 9]. Examples from some of my current research projects are presented to illustrate this alternative approach; one that is based more on exploring human values than simply offering prescriptive advice. Finally, I outline an overarching framework for guiding HCI that contrasts past and present concerns.

2 New Directions for Research

Several researchers have begun to reflect on the perspectives, paradigms and scope of the field of HCI. One trend has been to characterize the developments in HCI in terms of particular epochs or movements. For example, it has been argued that HCI research is entering a third paradigm that is much broader in its remit than the information processing approach of the 80-90s (described as the second paradigm) and the Human Factors work (labeled as the first paradigm) of the 70-80s [10]. Notions of context of use, the social situation of interaction, seamfulness and emotion are outlined as key research concerns, derived largely from sociology, design and the arts. They also propose that researchers seek multiple interpretations to obtain a “more complete overall understanding of the nature of interaction” of the phenomena being observed and analyzed. Similarly, a set of ‘third wave challenges’ has been outlined for HCI [11] but which suggests that the second wave (akin to the second paradigm) should not be abandoned but studied alongside them using a range of methods and conceptual approaches.

In a more far-reaching and forward-looking report, *Being Human*, Abigail Sellen, Tom Rodden, Richard Harper and myself [8] summarize the many changes afoot and suggest a new frame for understanding society’s relationship with technology. We propose that HCI needs to put human values centre stage, considering both positive and negative aspects of the diversity of new technologically-mediated experiences. In terms of positive experiences, we explore how people use technology to pursue healthier and more enjoyable lifestyles, expand their creative skills with digital tools, and instantly gain access to information never before available. In terms of negative

concerns, we explore how governments have become more reliant on computers to control and constrain society, criminals have become more cunning in deceiving people via digital means, and people worry more about what information is stored about them and who has access to it. We conclude by proposing that HCI researchers should be exploring this wider spectrum of user experiences, and in so doing, providing more in-depth explanations, accounts and implications that can inform the design, use and acceptance of future technologies, at personal, social and cultural levels. These outputs should also be of a form that can impact on government policy, in ways that move beyond simply providing guidelines for work practices or interface design.

In so doing, HCI will have to address a set of demanding, all-encompassing and socially awkward questions. To start the process, Being Human proposes five main transformations that are happening in society followed by a series of questions that need to be addressed for each. The changes are:

- the end of interface stability
- the growth of techno-dependency
- the growth of hyper-connectivity
- the end of the ephemeral
- the growth of creative engagement

2.1 The End of Interface Stability

The “interface” with computers is changing to such an extent that it is no longer as clear as when people interacted with PCs. At one end, situated displays and sensors are becoming embedded in buildings, airports and other public spaces, tracking our movements and displaying relevant information in these spaces, such as advertisements of products that are assumed to match our interests. At the other, our interactions with technology are becoming more personal and intimate. For example, we now carry in our pockets and our handbags multiple points of contact to a computational infrastructure. With the shift to medical monitoring and embedded devices this is likely to get closer still. Indeed, it may be difficult to define the boundary at all when devices are embedded within us.

The transformation in interface boundaries relative to our own bodies raises many new questions about how we might interact with new technologies. As the boundary moves closer to us, so the focus of the interaction needs to be better understood by the individual and how it will impact their own personal experience. As these devices become part of us, it raises issues about what defines an individual, and whether embedded devices are part of that definition. However, the issues are more complicated than this. Personal, intimate devices can be networked and therefore can interact with other people and other devices within the wider environment. We need to consider the spectrum of interfaces, ranging from private and personal interaction at one end to public and aggregated interaction at the other. At any one moment in time it means we can be simultaneously interacting with multiple boundaries, some under our control and some not. This causes shifts in what we will perceive as personal space, and what is shared.

2.2 The Growth of Techno-Dependency

The current generation of teenagers has grown up with the Web at their fingertips, instant availability through mobile phones, access to vast archives of their personal music and photographs, and video and TV on demand. They also take for granted older technologies such as calculators, word processors, and email. But what happens when the Internet or a mobile network provider goes offline? People become suddenly aware of their dependence, or even addiction, to email and the Web.

Techno-dependency raises a number of fundamental questions to do with what it means to be human. A controversial concern is the extent to which we will become increasingly dependent on computing technologies acting on our behalf, constantly reminding and telling us what to do. While it might make our lives easier it might come at a cost; for example, we might lose our mental ability to remember. But will this matter, if technology is always at hand [cf 1]?

Another topic that warrants systematic research is whether our ability to pay attention and focus is being affected by the multiple channels of digital information that can now be accessed simultaneously on a PC. Could it be that people who spend lots of time in front of a computer monitoring multiple sources of information are worse at switching between tasks and less able to focus exclusively on a single source? Recent findings suggest that it might be the case and that individuals who partake most in channel-hopping may also suffer the most. A recent study has found that participants who are 'heavy media multi-taskers' were worse at task switching than those classified as 'light media multi-taskers' because they were more susceptible to interference from irrelevant environmental stimuli and irrelevant representations in memory [12]. Hence, far from being able to deftly switch between multiple IM sessions, check up something on Wikipedia, play patience and an online game of chess, while apparently writing an essay, heavy media users are likely to be more easily distracted by the multiple streams of information and ongoing activities than those who are focused more on writing their essay and who may only allow themselves to check their email once every hour. Moreover, heavy users may actually be deceiving themselves: assuming they can benefit from multi-surfing and multi-tasking but which may prove to be more detrimental to them.

2.3 The Growth of Hyper-Connectivity

There has been an explosive growth in connectivity to individuals and society at large. People now connect 24/7 with many more people than ever before, be it friends, family, colleagues or strangers. Teenagers used to brag about how many friends they had online, but now take it for granted that everyone has several hundred 'friends' on Facebook. The boundaries between being at work, at home or out socializing are dissolving. It is accepted for people to be emailing or texting their colleagues in the early hours while playing a game of poker with people they have never even met.

Traditional, socially accepted conventions and etiquette governing how we communicate, when we communicate, and whom we communicate with are rapidly disappearing, with new ones replacing them. For example, students feel it is perfectly

acceptable to email their professors with excuses for late assignments using informal text slang. Professors, however, may feel differently. Spontaneously emerging codes of conduct are also appearing when using communication technologies. These include right and wrong behaviors, such as not looking at others or by abstaining altogether from using Facebook in particular contexts (such as when sitting next to a stranger on the bus). Moreover, in a recent study [13] it was found that those students who update others' status or those who use Facebook during classes can seem to be in conflict with the code of conduct that one would expect outside of the Facebook community and that this breach can suggest a privileged position inside that community (e.g., one's Facebook friends) or a judgment towards the outsiders (e.g., the lecturers).

Such hyper-connectivity and rapidly changing social rules raise a number of fundamental issues for understanding how people manage and cope with the increasing demands of perpetual communication. Are they able to adapt and keep up with the new social trends or is the basic human need to disconnect and spend time on their own, or with close friends and family, being detrimentally invaded?

2.4 The End of the Ephemeral

Another transformation that is taking place is the 'expanding digital footprint'. Increasing amounts of information – that previously was largely transient and ephemeral – are being recorded and stored permanently as digital data. These include verbal conversations, emails, photos, texts, blogs, tweets, online purchases, banking transactions, and video footage taken by CCTV cameras and personal cameras/phones. Furthermore, many of these are tagged and indexed. Photos of people taken at a party, school event or at a restaurant can end up appearing on Flickr with associated names but without the tagged people ever realizing or giving permission.

In addition, an assortment of sensors have been experimented with in our homes, hospitals, public buildings, physical environments and even our bodies to detect trends and anomalies, providing a dizzying array of digital data about our health, movements, changes in the environment and so on. A number of location and tagging technologies have been developed, such as RFID, satellite, GPS and ultrasonics, to enable certain categories of information to be tracked and detected. Smartphone applications are now appearing that enable details about people's whereabouts and itineraries to be tracked online as they travel. Again, such information can be without them ever being aware it is available to the public.

In the last few years, there has been an increase in 'assisted living' projects that aim to help elderly people to remain more independent. In one of the early projects a residential care home was wired throughout with a variety of sensors [14]. These included badges on the patients and the caregivers and switches on the room doors that detected when they were open or closed. Load sensors were also used to measure and monitor weight changes of people while in their beds; the primary aim was to track trends in weight gain or loss over time. But the sensors could also be used to infer how well someone was sleeping. If significant movement was detected during the night this could enable a caregiver to see whether the person was having trouble

sleeping (and if there was a huge increase in weight this could be inferred as someone else getting in or on the bed). More recently, researchers at the Fraunhofer Institute in Germany have been placing sensors in the toilet, tap, and carpet so that they can detect even more of an elder's intimate activities and record them electronically. They are even putting sensors in the toothpaste tube to record how frequently they are cleaning their teeth.

Such panopticon developments elicit a knee-jerk reaction of horror in many of us. While the motives behind such projects are altruistic, they can also be naïve, overlooking how vulnerable people's privacy and self-respect may be being violated. HCI researchers could make an important contribution by examining the social implications of recording, tracking and re-representing people's movements, conversations, actions and transactions, and whether a person's right to privacy being breached. For example, they could investigate whether different kinds of people mind their everyday habits, such as sleeping, eating, etc., being videoed and sensed, especially when they are not looking their best.

Case Study: A futuristic dieting system

One area where new technologies are being developed is for personal healthcare and wellbeing. While offering many benefits to people they can raise contentious issues pertaining to privacy, security and acceptance. How might HCI researchers begin to address these? Consider the following fictitious scenario developed by [15]:

“A company has developed a new wearable technology intended to help people lose weight called DietMon. The main character is Peter, a businessman in his early forties, who is overweight and would like to slim down. He claims he has been keeping a food diary, which shows that he does not eat that much. He also claims to be doing as much exercise as he can fit in with his busy life. However, nothing seems to be able to stop him gaining weight. So, the doctor invites him to try DietMon, a new technology that will assist him in his endeavor to slim down. He will have to wear glasses (fitted with clear lenses for those who don't normally wear them) that are enhanced with invisible cameras hidden in the frames; the cameras take a picture of every food that Peter looks at for more than three seconds and sends it to a database where the system cross-references it in order to identify the approximate number of calories contained in that food. The system will then send a text message to Peter's mobile phone to let him know. If Peter looks at a menu, the system identifies and sends him back the calorific value of each item in the menu. Peter will also have to have a tiny microchip implanted in his wrist, which will record the physiological changes taking place in his body as he eats (for instance, sugar or alcohol levels in the blood). The system sends the data recorded to his doctor, so that she can check whether he is keeping on track, and back to him, to keep him informed on how he is doing. As Peter approaches his daily calorific allowance, the system will send him an alert to let him know that he should stop eating. If he takes the glasses off or forgets to put them on, the microchip will still keep track of his food intake.”

To explore the privacy, security and trust concerns this scenario raises, we have developed a new method, called ContraVision. The scenario is represented as two videos, one portraying it in a positive light and the other in a negative light. The two videos take Peter through a series of situations in which he has to manage his

relationship with the technology, with food and with his family and colleagues. These are the same in both videos (e.g., having breakfast, walking past a cake shop, going for a meal) but the reactions and actions of Peter vary in subtly different ways for the positive and negative setting. For example, Fig. 1 is a still from the positive video, depicting Peter in a positive light. He is at a colleague's birthday party demonstrating how the dieting system works. Fig. 2 is a still from the negative video, showing Peter looking guilty as he is tempted to eat the pastry, when his wife opens the kitchen door.



Fig. 1. A still from the positive video. Peter gives his colleagues a demonstration of how the dieting system works. One of his colleagues is wearing Peter's glasses while Peter waits for the text with the calorie count to reach his mobile. (Mancini et al., 2009).



Fig. 2. A still from the negative video. Peter is about to be caught by his wife in the act of stealing a pastry from the fridge. (Mancini et al., 2009).

Participants from varied backgrounds viewed and discussed either the positive or negative video. A wide spectrum of reactions and concerns was elicited and which varied depending on the type of video watched. As might be expected, a number of topics were raised in both, including safety, trust, security, physical intrusion, possible uses and potential misuses of the information recorded and relayed and different forms of privacy breach. The videos also raised concerns that we were not expecting, including how the system would impact on their identity, self awareness, self

perception and self representation to others; different levels of openness and deception and stress deriving from the use of deception; levels of control and freedom, and pressure deriving from lack of these; intrusion in and influence on personal and social behavior.

Hence, what might appear as a seemingly benign personal healthcare technology, meant to help people lose weight by giving them up-to-date information about food they are tempted or wish to eat, could end up being a much more pernicious system that not only could invade an individual's privacy, but also their sense of identity and how they interact with others.

2.5 The Growth of Cognitive Engagement

The four transformations described so far have focused primarily on the potential negative concerns of our ever-expanding relationship with technologies. The case study above illustrated how we can begin to explore in-depth the personal, social and cultural aspects of future technologies. However, it should be stressed that there are many opportunities for novel technologies to be designed that can augment and enhance how people learn, live and work in positive ways. Recent commercial examples include embodied physical games, such as the Wii and collaborative learning technologies, such as multi-touch tabletops. Another creative development is the highly successful smartphone Apps that are designed by and for everyday people. A diverse range of experiences has been created providing people with many shared moments of fun and pleasure. A very popular music example is Shazam (www.shazam.com) that lets the mobile phone user find out which commercially recorded song is currently playing from any loudspeaker (e.g., radio, TV, stereo) that they can then share with their family and friends.

Innovative mixed reality, physical-digital spaces and sensor-rich physical environments have also been developed in Ubicomp research that enable people to engage and use multiple representations in novel ways: in scientific and working practices and in collaborative learning and experimental games. One example, that pioneered a new approach to augmented learning as part of the EQUATOR project, was the Hunting of the Snark game designed for young children [16]. The goal was to provoke their imagination and reflection through novel couplings of physical activities and digital representations. Pairs of children, aged between 6-8, had to discover as much as they could about an imaginary creature, called the Snark – its appearance, its likes and dislikes – by physically interacting with it in various activity spaces. The children had to perform certain kinds of embodied actions in these spaces, such as flying, dancing, walking and feeding. The Snark never appeared in its entirety but only as digital glimpses (animations, sounds and images) in response to the children's physical actions. The Snark responded by crying, laughing or showing appreciation or disgust to what it was fed. Children who played the game were fascinated by the abstract representations of the Snark that surfaced in the activity spaces and tried to work out how their physical actions caused them to appear. After the game, the children often gave lengthy narratives of the Snark's personality and behaviors that were based on their different glimpses when flying, dancing and feeding it.

A question when developing novel ubiquitous applications for creative engagement is how do they compare with those offered by more conventional GUI interfaces – that can be much cheaper and more practical to make? For example, is it not the case that children can be highly creative and imaginative when given simply a cardboard box to play with? If so, why go to such lengths to provide them with new tools? The debate is redolent of whether it is better for children to read a book or watch a 3D Imax movie. One is not necessarily better than the other: the two provide quite different experiences, triggering different forms of imagination, enjoyment and reflection. Likewise, ubiquitous technologies can be developed to both provoke and stimulate, and in doing so promote different kinds of learning and collaboration. Combining physical interaction, through manipulation of objects or tools or through physical body postural movement and location, with new ways of interacting, through ecologies of inter-connected digital technologies offers new opportunities compared with interacting solely with digital representations or solely with the physical world. In turn, this can encourage or even enhance further exploration, discovery, reflection and collaboration.

3 Proactive People Rather than Comfortable Living

I have argued how human values need to become more central in HCI research, where researchers explore both positive and negative aspects, at personal, social and cultural levels. In addition, I argue that we need to design new technologies to encourage people to be proactive in their lives, performing ever greater feats, extending their ability to learn, make decisions, reason, create, solve complex problems and generate innovative ideas [9]. Such a view, however, is in sharp contrast with the prevailing vision of ‘calm computing’ that has influenced much of the research in ubiquitous computing, that was originally proposed by Mark Weiser in the early 90s. I argue why it is timely to move on and consider how ubiquitous computing can engage people.

Weiser's [17] central thesis was that while “computers for personal use have focused on the excitement of interaction...the most potentially interesting, challenging and profound change implied by the ubiquitous computing era is a focus on calm.” Given the likelihood that computers will be everywhere, in our environments and even embedded in our bodies, he argued that they better “stay out of the way” and not overburden us in our everyday lives. His picture of calm technology portrayed a world of serenity, comfort and awareness, where we are kept perpetually informed of what is happening around us, what is going to happen and what has just happened.

In the last 15 years, Weiser has inspired governments, researchers and developers across the globe. Most prominent was the European Community's Disappearing Computer initiative in the late 90s and early 2000s, that funded a large number of research projects to investigate how information technology could be incorporated into everyday objects and settings and to see how this could lead to new ways of supporting people's lives that went above and beyond what was possible using desktop machines. Other ambitious and far-reaching projects included MIT's Oxygen,

HP's CoolTown, IBM's BlueEyes, Philips Vision of the Future and attempts by various telecom companies and academia to create the ultimate 'smart home', e.g., Orange-at-Home and Aware Home. A central aspiration running through these early efforts was that the environment, the home, and our possessions would be aware, in order to adapt and respond to our varying comfort needs, individual moods and information requirements. We would only have to walk into a room, make a gesture or speak aloud and the environment would bend to our will and respond or react as deemed appropriate for that point in time.

Considerable research effort has been spent realizing Weiser's vision in terms of the development of infrastructures, devices and applications – to enable people to live calm lives. My beef with this approach is that as advanced and impressive as these endeavors have been in ubiquitous computing research (UbiComp) they still do not match up to anything like Weiser's world of calm computing. There is an enormous gap between the dream of comfortable, informed and effortless living and the accomplishments of UbiComp. As pointed out by Greenfield [18] "we simply don't do 'smart' very well yet" because it involves solving very hard artificial intelligence problems that in many ways are more challenging than creating an artificial human.

In contrast, I argue that a more productive direction for ubiComp research is to augment everyday activities using the portability, pervasiveness and computational power of ubiquitous infrastructures and mobile devices [5]. This idea essentially builds on Doug Engelbart's pioneering research program in the 60s for using distributed computer technology to augment the human intellect. By this he meant increasing the capabilities of a person so that they could make more rapid decisions, understand complex situations and find solutions to problems that seemed insoluble without the aid of technology. His ultimate goal was to develop technologies that could help people solve the world's increasingly complex problems. His approach was to show how the computing technology of the day could be designed to manipulate information directly, and which could thereby enable a new way of thinking about how humans work, learn, and live together. Despite his technological successes – notably the invention of hypertext, GUIs and the mouse – Engelbart's [19] research agenda for how computing could improve human life has not had the impact it should have had [20]. For example, Alan Kay and Andries Van Dam have recently lamented today's practitioners' lack of curiosity and awareness of historical context, "we're incredibly wedged...conceptually, technically, emotionally, and psychologically into a tiny and boring form of computing that is not even utilitarian." [quoted in 20].

In revisiting Engelbart's original idea, we can think more generally about how human behavior rather than the human intellect can be augmented with personal, social and cultural technologies, which aim to *actively* extend what people can do. In addition, we can begin to experiment with new technologies that might begin to shed light on elusive philosophical and psychological questions about the mind and human behavior that have taxed researchers for centuries. Hence, augmentation can be both enlightening and empowering. To illustrate how this might be achieved, I present two examples from my ongoing and future research projects, called e-sense and CHOICE.

The e-Sense Project: Extending Minds, Senses and Bodies

The e-sense project is funded by the UK's Arts, Humanities, Research Council (AHRC) as speculative research to investigate the theory of the Extended Mind [1] and explore how our mind and senses can be extended through designing novel technologies. The extended mind views the human cognitive system as a plastic hybrid of biological and non-biological components, including external representations and technologies. This perspective has profound implications for our notion of what it means to be human, pointing to the potential to change thought and action by integrating new technologies and information sources. Our approach has been to create an array of vibro-tactile interfaces and monitor both their use and the user experiences [21, 22]. From this we can gain knowledge about how to build useful sensory augmentation technologies as well as important insights into the extended mind perspective. In our interdisciplinary approach, conceptual philosophical analysis feeds into the design of systems and user studies reciprocally feed back into philosophy.



Fig. 3. A prototype of a motion capture and vibro-tactile feedback system for tracking and improving bowing actions when learning to play the violin [from 23]

We have also begun to develop vibro-tactile technologies that increase children's awareness of their body posture when they are learning to play stringed instruments and when singing. Initial studies using motion capture technology to track bowing actions coupled with visual and vibro-tactile feedback have shown how different forms of multi-modal feedback that corresponds to 'corrective' tracking are effective

techniques that can improve technique [see Fig. 3]. We are currently developing other engaging and playful tools that can motivate children to practice regularly [23].

The CHOICE Project: Instant Information For In Situ Decision-Making

The CHOICE project is concerned with how new forms of augmented reality can be exploited to enable people to have ‘instant information’ at their fingertips that help people make more informed choices about values they care about when confronted with multi-dimensional information. Augmented Reality (AR) is becoming available that uses Smartphones and other ubiquitous technologies. For example, Pattie Maes (Media Lab, MIT), in her much talked about 2009 TED presentation, demonstrated how her team’s “6th Sense” wearable device, comprising a wearable camera, a mirror and a tiny battery-powered Pico projector could superimpose relevant digital information onto the surfaces in the environment, like people’s hands, clothing and food packaging. QR Codes (unique black and white chequered boards) are appearing on consumer products that when photographed, using an enabled mobile phone, will instantly bring up a game, video or informative website.

Our research project is investigating whether instant information provided by mobile AR can make it easy for people to do the right thing in the context of food shopping. We are examining, firstly, whether people can read and act upon such ‘instant information’ and secondly, whether AR has the desired galvanizing effect; encouraging and empowering people to act upon various social causes (e.g., reducing carbon emissions) or improve their well-being (e.g., changing their diet). Rather than providing more information to enable consumers to compare when making a choice, we propose a better strategy is to design technological interventions that provide just enough information and in the right form. Our solution is to exploit new forms of augmented reality technology to enable ‘information-frugal’ decision-making, in the context of an intensive activity replete with distractions (i.e., shopping in a supermarket or deciding at the kitchen table what to have for dinner). To this end, we are developing a family of mobile, social and computational devices that will display visualizations of multi-dimensional data at opportune times to see if it can help people make more informed decisions.

Recent research in cognitive psychology has shown how people tend to use simple heuristics when making decisions [24]. A theoretical explanation is that human minds have evolved to act quickly, making ‘just good enough’ decisions by using fast and frugal heuristics. People typically ignore most of the available information and rely only on a few important cues. In the supermarket, shoppers make snap judgments based on a paucity of information, such as buying brands they recognize, are low-priced, or have attractive packaging [25]. This raises the question of whether people can pay attention to more information, such as nutritional, ethical, and environmental features, regardless of whether it is instant relevant information. Rather than simply providing more information that enable consumers to compare when making a choice, we are determining how to design technological interventions that provide just enough information and in the right form.

4 New Directions for Practice

So far I have explored new directions for HCI research. In this part of the paper, I consider new directions for HCI practice. During the last 10 years, significant strides have been made already in academe and industry, to develop an armory of methodologies and practices. Innovative design methods, unheard of in the 80s, have been imported and adapted from far afield to study and investigate what people do in diverse settings. Ethnography, informant design, cultural probes, experience sampling and scenario-based design are examples of these. New ways of conceptualizing the field are also emerging. For example, many aspects of the user experience (UX) and ways of measuring it have been articulated by practitioners and are now common parlance. The focus is more on what is being done (i.e., designing interactions) and felt (user's experience) rather than the components it is being done to (i.e., the computer, the human). The nature of the user experience and how it unfolds over time is measured by its subjective qualities, such as what interacting with a device feels like to use, e.g., a MP3 player or a pet robot. Concepts such as pleasure, aesthetics, fun and flow, on the one hand, and boredom, annoyance and intrusiveness, on the other, have been used to describe the multifaceted nature of such experiences. The whole life cycle of people's response to technology is also being detailed, from when it first grabs their attention and entices them, through their ongoing relationship with that technology.

New measuring instruments (e.g., eye tracking) are also emerging that can record in fine detail how the body and senses are engaged when interacting with new computing developments – whether it be a new mobile social network service, a blue-toothed enabled GPS system or the latest web advertising. While surveys, user testing and expert reviews persist as staples alongside the classic user-centered design methods, such as storyboarding, scenarios, and low-tech prototyping methods, new technical innovations are turning heads. For example, the current wave of interest in multivariate tools (e.g., AB testing) that enable closer coupling between design and testing of live website components is one such development.

Practitioners are reinventing themselves to keep up with the technological and life style changes in our midst. But is this enough? Can and should they be considering the wider spectrum of human experiences, especially those that focus on positive and negative human values? A difficult challenge is how they can capture and analyze the bigger picture in terms of requirements, design recommendations, principles and implications. Consider the following hypothetical scenario for which a new system has been developed (again for personal healthcare but for which commercial products actually exist):

The number of children diagnosed with Type 2 Diabetes is on the rise, worldwide – a disease that requires constant management and can be very stressful for all concerned. A medical company has developed a new 'well being' monitoring device that periodically sends the latest recording of the child's blood sugar level to subscribing remote cell phones. A goal is to provide reassurance for parents that their child's condition is stable during school time when they are not around to assist.

A UX consultancy company has been hired to assess the usability of this service. How might they accomplish this?

An obvious starting point would be to test the legibility and appropriateness of the recordings sent from the monitoring device to the cell phones. Is the form of representation used to convey the readings reassuring to the parents at a glance or do they have problems understanding what they mean, especially when the sugar levels vary from what they expect at that time of day? Are the danger warnings set at the right level? But then there are behavioral measures that need to be considered to determine whether the service is reassuring: How often do the parents use the service on their mobile phones? Do they get more anxious when calling it? What do they think each time they read it? Do they feel the urge to call their child? Should the device also communicate what activities the child is engaged in? And so on.

In conjunction, the UX of the wearer of the monitoring device – in this case the child – would need to be assessed. This raises a whole set of additional questions: Would the child have any control over what and when the recordings were relayed or would it be automated? Should the device signal to the child whenever a parent has called in to get a reading? What happens if the parents don't call in for sometime? Will the child worry? Will the child become more dependent on them? How often does the child look at the readings? Do they get more or less anxious knowing their parents are looking out for them? Will they think their parents are checking up on them and they would rather they didn't? And so on.

This scenario is representative of many others on the brink. The monitoring of others, the capture of, access to and management of people's personal information, however benign in its intentions, is likely to pervade all aspects of our personal lives. It is no longer enough that practitioners think about how best to design and evaluate applications or services for users, they need also to think about how the technologies will be used by and affect networks of users, such as families, communities and different social groups. A challenge facing practitioners, therefore, is to consider how the more elusive ethical, personal and wider societal concerns can be folded into the UX mix such that they can be sensibly addressed when designing new technologies and services. How realistic and feasible is it? Many of the concerns may not be amenable to their repertoire of methods, usability metrics and design solutions. Moreover, the thorny ones are unlikely to be fixed in the way in which products (sic) have been improved through suggested changes. There is also likely to be several conflicting issues and complex webs of issues.

Taking into account human values, therefore, will be a very different undertaking compared with seeking to attain the design goals of efficiency, effectiveness and utility. Design trade-offs need to be considered not in terms of time and errors, but in terms of the weighing up of the various moral, personal and social impacts on the various parties who will be affected by the proposed technology. In the Being Human report we argue for the inclusion of a new stage in the user-design process, coined 'understand' (see Fig. 4). While understanding a problem has traditionally been part of the initial study phase, we are proposing that it be elevated to be a more explicit process, where the various human values at play are thought through and the trade-offs examined in a more systematic and sensitive way.

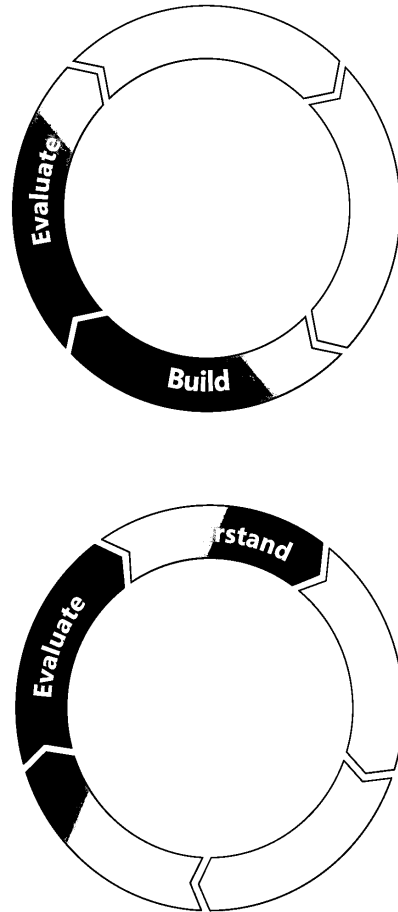


Fig. 4. *Top:* The conventional user-centered research and design model. *Bottom:* The extended five-stage research and design model encompassing a new stage of conceptual analysis or “understanding “ of human values (from Harper et al., 2008).

A new set of thinking tools are also needed to fill the ‘understand’ phase, ones that can be used to articulate and resolve the differing sets of values and questions arising from them. Philosophical debate, thought experiments and scenarios are promising candidates for starters. However, practitioners can go one step further: developing accessible frameworks and models that will enable them to explore through a new form of argumentation, and map out the interplay of moral, social and personal issues with their clients.

5. Conclusions: Framing HCI Research and Practice

I have suggested new directions for HCI research and practice that cover a broader spectrum of concerns than other recent agendas have promoted, such as the third paradigm [10] and third wave [11]. This requires moving beyond ‘felt experiences’ and ‘enjoyable/comfortable living’ philosophies that have permeated much recent research to encompassing a range of ‘difficult’ questions that focus on human values and augmentation of the human senses, mind and body. Examples from some of my current research projects were presented to illustrate this alternative approach.

A motivation was to begin rethinking the contribution the HCI community can make to understanding our changing relationship with technology. When asked what I do for a living I find it increasingly hard to explain in a sentence, in the way I used to be able to 10 years ago (designing computers to be easy to use). Instead, I fumble with phrases, such as ‘designing engaging computer interfaces’, ‘what it means to be human in a world full of computers’, and ‘I research mobile and sensor-based technologies that can track your every move’ and use examples such as the iPhone and the Surface by way of illustration. Maybe I just need to practice a new elevator talk but, seriously, we are in need of a set of new terms, descriptions, and other abstractions that articulate the concerns we are interested in and the purpose behind what we do – and which, importantly, researchers, practitioners and the general public understand and feel comfortable using. We need to begin to engage in more dialogues, identifying areas of conceptual richness and problem articulation.

Table 1 presents my attempt at framing the burgeoning scope of HCI in the age of ubiquitous computing. It contrasts past concerns with future ones along four dimensions. Firstly, in terms of a frame of reference, it suggests that HCI’s focus on users should be replaced with context. This shift reflects the broadening of issues, covering personal, social and cultural aspects of technology use and augmentation. Secondly, it notes how the methods, theory and perspective of HCI have in the past followed either the scientific approach (e.g., conducting experiments based on cognitive theory and doing user testing) or interaction design (e.g., prototyping, user studies, ethnography) should be replaced with multiple methods (including experiments and ethnography) that previously might have been considered incommensurate, but which can be mixed and even mashed in order to probe and analyze the wider and sometimes elusive set of concerns. Thirdly, it suggests that the current way of working together inspired by interdisciplinarity should make way for more transdisciplinarity. The ‘trans’ refers to integrative knowledge based on the convergence of concepts and methods from different research areas, including computing, philosophy, embodied psychology, art and design, ethics and engineering. It involves moving between the big picture and the details of a research question, using a combination of strategies, design methods and theories. For example, this might involved the application of philosophical theory to technological innovation, where conceptual philosophical analysis is fed into the design process and the experiences of being engaged in user studies are fed back into the philosophical analyses. Fourthly, whereas in the past, outputs from HCI research and practice have been either accounts or rich descriptions from ethnographic research; models of the user or the user experience; and conceptual or evaluative tools for analysis, future

outputs should provide insights into how to develop engaging user experiences and human augmentation that, importantly, explore the whole gamut of human values that are impinged upon.

Frame of reference	• users	• context
Method, theory and perspective	• scientific approach • interaction design	• multiple • mixing and mashing
Working together	• interdisciplinarity	• transdisciplinarity
Outputs	• ethnographies • models and tools for analysis • design guidance	• insights • creating new ways of experiencing • value-based analyses

Table 1. Framing past and future concerns for HCI

Acknowledgements

The projects mentioned in the paper have been partly funded by the EPSRC (PRiMMA) and the AHRC (e-sense). Thanks to Abigail Sellen, Tom Rodden and Richard Harper who co-authored ‘Being Human: HCI in the Year 2020’ with me.

References

1. Clark, A.: *Supersizing the Mind*. Oxford University Press, Oxford, UK (2008)
2. Rogers, Y., Price, S.: How mobile technologies are changing the way children learn. In: A. Druin, (Ed.) *Mobile Technology For Children*. Elsevier, Burlington, MA. (2009) 3-22
3. Barnard, P.J., May, J., Duke, D.J., Duce, D.A.: Systems interactions and macrotheory. *Transactions On Computer Human Interaction*, 7 (2000) 222–262
4. Rogers, Y.: New theoretical approaches for human-computer interaction. *Annual Review of Information, Science and Technology*, 38 (2004) 87-143
5. Rogers, Y.: Is HCI in danger of spiraling out of control? *interactions*, 64 (2005) 8-9

6. Grudin, J.: Is HCI homeless? In search of inter-disciplinary status. *interactions*, 13 (1) (2006) 54-59
7. Grudin, J.: Living without parental controls: the future of HCI. *interactions* 14(2) (2007) 48-52
8. Harper, R., Rodden, T., Rogers, Y., Sellen, A.: *Being Human: HCI in the Year 2020*. Microsoft (2008)
9. Rogers, Y.: Moving on from Weiser's vision of calm computing: engaging Ubicomp experiences. In: Dourish, P. et al. (Eds.) *UbiComp Proceedings, LNCS 4206*, Springer, (2006) 404-421
10. Harrison, S., Tatar, D., Sengers, P.: The three paradigms of HCI, *alt.chi, CHI'07*, ACM, New York (2007)
11. Bødker, S.: When second wave HCI meets third wave challenges. In: A. Mørch, K. Morgan, T. Bratteteig, G. Ghosh., D. Svanaes, (Eds.): *Proceedings of the 4th Nordic Conference on Human-Computer Interaction: Changing Roles*. ACM, New York (2006) 1-8
12. Ophir, E., Nass, C., Wagner, A.: Cognitive control in media multitaskers. *PNAS Early Edition online* www.pnas.org/cgi/10.1073/pnas.0903520106
13. Mancini, C., Thomas, K., Rogers, Y., Price, B.A., Jedrzejczyk, L., Bandara, A., Joinson, A.N., Nuseibeh, B.: From spaces to places: emerging contexts in mobile privacy. To appear in: *Ubicomp Proceedings, LNCS*, Springer (2009)
14. Beckwith, R., Lederer, S.: Designing for one's dotage: *UbiComp and Residential Care facilities*. Conference on the Networked Home and the Home of the Future (HOIT) (2003) www.crito.uci.edu/noah/HOIT
15. Mancini, C., Rogers, Y., Bandara, A., Coe, T., Jedrzejczyk, L., Joinson, A.N., Price, B.A., Thomas, K., Nuseibeh, B.: *ContraVision: Widening the spectrum of users' reactions and concerns to personal technology*. Submitted to *CHI'10*, ACM, New York (2010)
16. Rogers, Y., Muller, H.: A framework for designing sensor-based interactions to promote exploration and reflection. *International Journal of Human Computer Studies*, 64 (1) (2006) 1-15
17. Weiser, M.: The computer for the 21st century. *Scientific American*, 265 (3) (1991) 94-104
18. Greenfield, A.: *Everyware: The Dawning Age of Ubiquitous Computing*. New Riders, Berkeley, CA (2006)
19. Engelbart, D.: Engelbart, D.C. *Augmenting human intellect: a conceptual framework*. SRI Report, AFOSR-3233 (1962)
20. Frenkel, K.A.; A difficult, unforgettable idea. *CACM*, 52 (3) (2009) 21
21. Bird, J., Holland, S., Marshall, P., Rogers, Y., Clark, A. *Feel the Force: using tactile technologies to investigate the extended mind*. *Proceedings of Devices that Alter Perception (DAP08)* (2008) 1-4
22. Bird, J., Marshall, P., Rogers, Y.; *Low-Fi Skin Vision: A case study in rapid prototyping a sensory substitution system*. In: *Proceedings of the 23rd Conference on Human Computer Interaction 09*, Cambridge, UK (2009)
23. Van der Linden, J., Schoonderwaldt, E., Bird, J.: *Towards a real-time system for teaching novices correct violin bowing technique*. In: *Proceedings of the International Workshop on Haptic Audio-Visual Environments and Games*,

HAVE, IEEE Instrumentation and Measurements, to be held November 2009, Italy (2009)

24. Gigerenzer, G., Todd, P. M. et al.: Simple Heuristics That Make Us Smart. New York, Oxford University Press (1999)
25. Todd, P.: How much information do we need? European Journal of Operational Research, 177 (2007) 1317-1332