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Making Visible

Mediating the material of emerging technology

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Timo Arnall
Oslo, December 2013

Abstract

In this thesis I outline how interaction design may engage in the exploration and understandings the material and mediation of new interface technologies. Drawing upon a design project called Touch, that investigated an emerging interface technology called Radio Frequency Identification or RFID, I show how interaction design research can explore technology through material and mediational approaches. I demonstrate and analyse how this research addresses the inter-related issues of invisibility, seamlessness and materiality that have become central issues in the design of contemporary interfaces. These issues are analysed and developed through three intertwined approaches of research by design: 1. a socio- and techno-cultural approach to understanding emerging technologies, 2. through material exploration and 3. through communication and mediation. When taken together these approaches form a communicative mode of interaction design research that engages directly with the exploration, understanding and discussion of emerging interface technologies.

I find that RFID interface technology can be explored through a combination of multi-mediational visual investigations, both analytical and productive, that construct new perspectives on the technology. These new views challenge existing views of the technology as a 'seamless' and 'immaterial' phenomena, showing that it has both cultural meanings and material phenomena. The main contribution of this thesis is a range of concepts that offer cultural, material and communicative perspectives on emerging technologies. The study builds a body of knowledge about RFID and related emerging technologies, that demonstrates potential of these concepts and approaches.

Chapter 1
Discovering mediational material

In this chapter I begin first by describing the contemporary landscape of highly visible and invisible interfaces which sets the stage for the questions posed by the thesis. I then outline an overview and focus of the research, with a central research question. I follow this with a short anecdote that recounts the starting point of the research, and this is supported by some key concepts and methods. The three key approaches used throughout the thesis are then described.

Figure 1: The use of the smartphone is perhaps the most visible aspect of contemporary, digitally-mediated, everyday-life. Yet the complex networks of systems and infrastructures that allow a smartphone to operate remain largely invisible and unknown.

The visible and invisible landscape of interfaces

The development of interface technologies has outpaced our ability to fully understand and critique them. In less than thirty years we have transitioned from text-based interfaces, through mouse and window driven interaction, to ubiquitous mobile interfaces and touch-screens (Figure 1), to tangible and embodied interaction. The scale and breadth of these developments, from global networks down to microscopic silicon in our pockets has meant that politics, economics, sociology, even design research has struggled to understand, explain and question technological development.

Figure 2: Interfaces and the networks that support them are now part of everyday life. What would have been remarkable just five years ago; a tablet with ubiquitous internet, is an unremarkable aspect of a graffitied street billboard.

Software and networked interfaces have become highly visible in culture and society, we are surrounded not just by the bright, bubbly visual interfaces of smartphones, but also by ubiquitous advertising for interfaces in cinema, on TV and billboards such as Figure 2.

Indeed, the visual occupies a highly prominent role in culture, bolstered by the emergence of digital interaction as observed by Kress (1998). The visual interfaces to information and interaction have become central cultural artefacts. Visual interfaces are now central diagetic artefacts in cinema, providing the foundation for the plot of blockbuster films (Kirby 2011) Interfaces and networks are regularly discussed in popular media, their social effects are discussed in lifestyle sections, their political implications often headline news (such as Figure 3, below), their economic effects occupying the financial pages, while games and apps are reviewed alongside film and the arts. Although interfaces are now highly "visible, present and branded" (Bell & Dourish 2007), the means of using the visual to explore and explain interfaces , in order to build knowledge, to discuss, debate and critique them are still rather under-developed. In particular, perspectives and approaches that open up for exploring and shaping the cultural understandings of interface technology require more attention in interaction design research.

Figure 3: Popular media regularly plays on the curiosity, magic and uncertainty around technology, here a story about finding Russian spies through their use of WiFi networks.

These problems of understanding and explanation are currently being compounded by the disappearance of computing infrastructures and interfaces into the fabric of everyday life. There are an increasing number of interfaces embedded in the physical world, such as cameras, sensors and wireless systems that are often not just metaphorically but literally invisible. As seen in Figure 4 below, the signs for otherwise invisibly embedded infrastructure like WiFi are necessarily being designed alongside other kinds of public signage, in order to alert the public to the potential (or constraints) of these new wireless interfaces.

Figure 4: Wifi is just one of many invisible, networked infrastructures that are emerging into the fabric of everyday life, that require new forms of visual signage and explanation.

In much of the discourse around the development and design of interfaces, the emphasis has been on the invisibility of technological systems (e.g. Spool 2009, Norman 1998). The central cultural icon of our

age, the smartphone, is a smooth black rectangle, that even goes as far as hiding the edges of the large screen embedded in its surface. The move towards "seamless" interfaces are in response to the perception that interfaces have become too dominant, taking over our senses in ways that demand too much of our attention. Phrases like "The best design is invisible", and "the best interface is no interface" are amongst common phrases uttered as part of popular design discourse. These literally seamless surfaces represent the "deliberate "making invisible" of the variety of technical systems, artifacts, individuals and organizations that make up an information infrastructure" (Ratto 2007:21). Seamlessness and invisibility are increasingly persuasive concepts that are widely used in interaction design to describe qualities of digital systems and infrastructures.

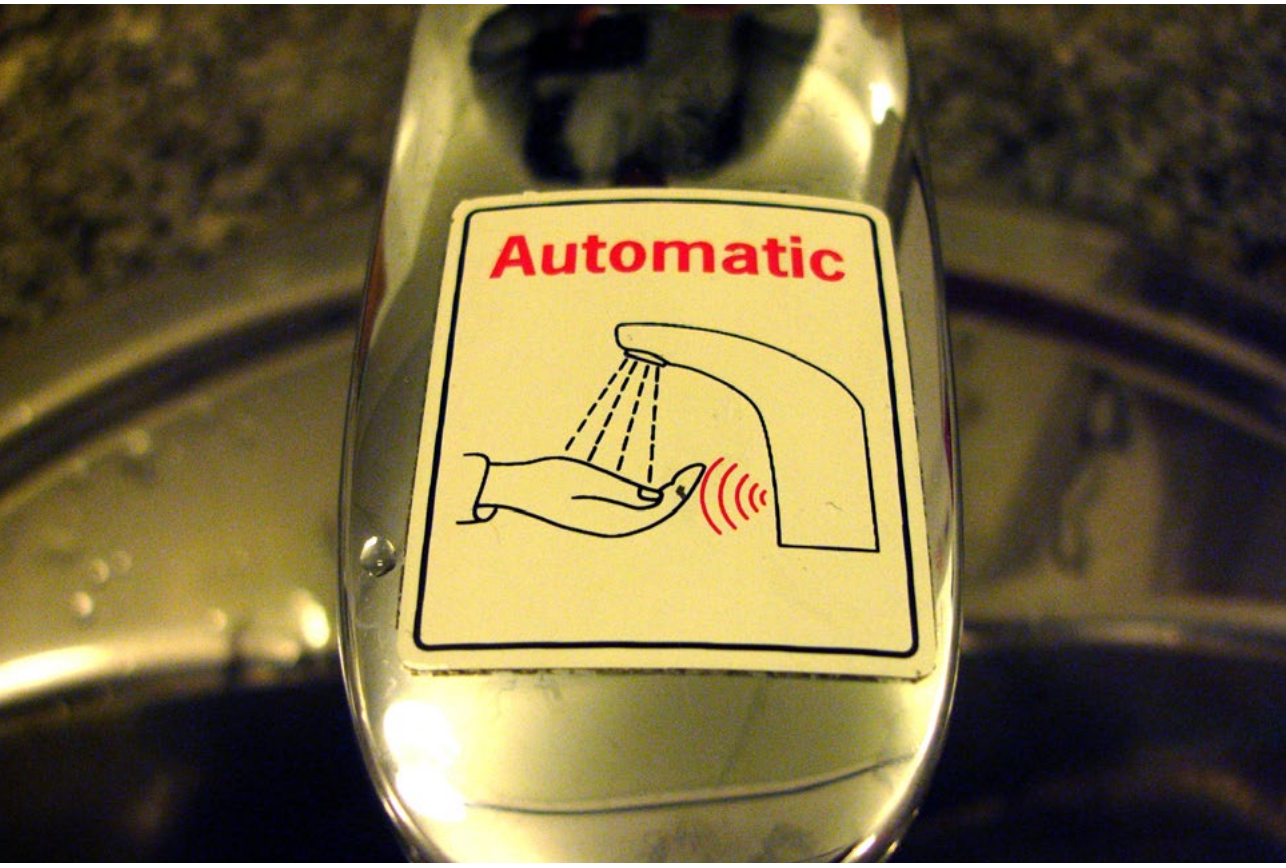

Figure 5: An invisible interface; an automatic tap, that has been made visible through retro-fitting with a visual diagram explaining its use.

Seamlessness and invisibility offer persuasive, desirable visions of interaction, the promise that we might not need to constantly attend to our digital devices, that interfaces might somehow be smarter and less intrusive. However, as we can see in Figure 5 above, even the simplest of interfaces cannot remain invisible without causing confusion and requiring visual interventions to reveal and explain its function. Even so, the focus on seamlessness has meant that there is little design practice or research that looks into making interface technologies apparent, or into revealing and explaining how they work. Instead there has been a process of hiding, covering up, of designing and of maintaining a pretence that the technologies that make up our daily interactions do not exist. Greenfield notes that:

> The complex technologies the networked city relies upon to produce its effects remain distressingly opaque, even to those exposed to them on a daily basis. (Greenfield 2009:online)

The context for this study is in the shearing forces between the increasing cultural presence and visibility of interface technology, and the deliberate, literal disappearance of technological phenomena. These issues have significant consequences for the way designers and the public build knowledge about interface technologies. This thesis develops perspectives and approaches to using the visual as a means of exploring and revealing invisible interface technologies.

Overview, focus and questions

In this thesis I outline how interaction design may engage in the exploration and understandings the material and mediation of new interface technologies. I demonstrate and analyse how interaction design research might address the inter-related issues of invisibility, seamlessness and materiality that have become central issues in the design of contemporary interfaces. It investigates a particular emerging interface technology called Radio Frequency Identification or RFID, that was originally developed from radar systems and is now used to identify objects at a distance through small embedded tags and readers.

These issues are analysed and developed through three exploratory and inventive approaches: 1. a socio- and techno-cultural approach to building knowledge about emerging technologies, 2. through material exploration and 3. through communication and mediation. When taken together these approaches form a communicative mode of

interaction design research that engages directly with the exploration, understanding and discussion of emerging interface technologies.

The central question I address is:

> ***How may interaction design as a material and communicative practice intervene in the technocultural imagination of RFID?***

In addressing these questions, the thesis takes up the challenges for interaction design research in the exploration and communication of new interactional materials. Implicit in this are a number of related issues.

- *How can visual means be used to explore the phenomena of RFID and other emergent interface technologies, and what competencies and concerns are involved in this investigation?*

- *How can interaction design materials be analysed and shaped through their visual mediation, and how does this become productive and generative of new concepts and perspectives on RFID?*

- *How can we approach highly technical and solution-oriented landscape of emerging technologies like RFID, through alternative perspectives and approaches?*

- *How might we frame a culturally-inflected, material-centric and communicative design research process?*

To respond to these questions by design and through analysis, the thesis focuses on three kinds of interconnected design research approaches that involve culture, material and communication detailed in Chapter 2 and 3. Each of these makes visible the material of RFID interaction in different ways, through various means of design production and analysis. These practices are presented and analysed through a multimediational mixture of text, photographs and films.

In the next section, I outline the starting point of the research, and why it became important to start to address the invisible materials of interaction design through media.

Making invisible materials visible

In the thesis I combine the use of images, videos and anecdotes to illustrate the research. The use of images and films as an integral part of the research work, I attempt to reflect the nature of the multimediational aspects of the design work more faithfully. By using approaches such as the anecdote, a "focused form of accounting" (Michael 2012), I aim to compress the insight from design practice into this thesis document in a way that would be lengthy and difficult using more formal writing techniques. Through the visual rhetoric of this thesis, using photography and embedded films, I will make visible both the invisible technical phenomena that we explored and the practices and understandings that made this possible. I now introduce the context of the research with a small anecdote about the early development of our material and mediational approach to RFID.

Figure 6. Project participants in an early workshop in 2006, exploring and playing with RFID components and products.

The project that this thesis emerged from, called *Touch*, began in early 2006 with an initial brief to research and design interfaces for innovative products and services around RFID technology. Touch was an interdisciplinary design research project, funded by the Norwegian Research Council's Information and Communication Technologies research fund, and based in the fledgling interaction design department at the Oslo School of Architecture and Design. The project thus emerged from two distinct areas, answering to funding a funding body that was heavily invested in Informatics and Human Computer Interaction (HCI) but also with the design sensibilities of an interaction and industrial design institute.

The Touch project partners included design researchers, an anthropologist, engineers and educators, concerned with building knowledge about RFID interaction from many perspectives. The project also took place in collaboration with the design studio BERG, that was concerned with the cultural, practical and commercial implications of RFID, and who also wanted to develop knowledge about technical materials as a platform for invention and innovation.

In essence, RFID technology is a method of allowing a computer to identify physical objects. It consists of a powered 'RFID reader' that transmits radio signals that are picked up, modified and returned by simple, inexpensive, battery-less 'RFID tags'. This usually works over short distances, so RFID is generally used by bringing an object with an RFID tag into close proximity (about 5cm) of an RFID reader. By embedding RFID tags in objects, typically credit cards or travelcards, computers can identify them and create transactions that are achieved by simply 'touching' objects together. In 2006 RFID interfaces were already ubiquitous in many cities for ticketing and access control for example London's Oyster card, while research showed something like four billion RFID tags in use around the world. Much contemporary research was directed towards using RFID in mobile phones to allow for "physical browsing" (Valkkynen 2007), or towards using RFID tags in exhibitions where visitors could interact with exhibits in ways that tracked what they did and personalised the experience (Hsi & Fait 2005).

In response to this we identified areas that were not being explored and became interested in how RFID could be used in consumer products and in playful experiences. We ran what could be called a traditional research-by-design process, in a design studio setting where we sourced components, worked with programmers, and built prototypes and demonstrators. We also studied instances of RFID interfaces in the

world; how did they work, how were they designed and how were they represented through visual instruction? This was accompanied by studies of the marketing and the research around RFID to uncover how the potential use of RFID was being scripted and framed.

However, after thousands of hours of study, many prototypes and conferences later, we began to realise that we did not yet have a clear enough understanding of RFID technology itself. We felt somewhat burdened and blinded by the dominant visions from retail, technology marketing, logistics industries and user-centred research. This lack of technical understanding felt debilitating to us as designers and researchers.

To address this I organised an event called the "RFID hacking workshop" (see Figure 6) where our team and project partners worked together in a room for a few days, surrounded by RFID components, motors, electronics and other hardware, exploring, thinking, sketching and making. The project participants were chosen for their mix of competencies, from visual design to technology research, very used to working in-between these domains.

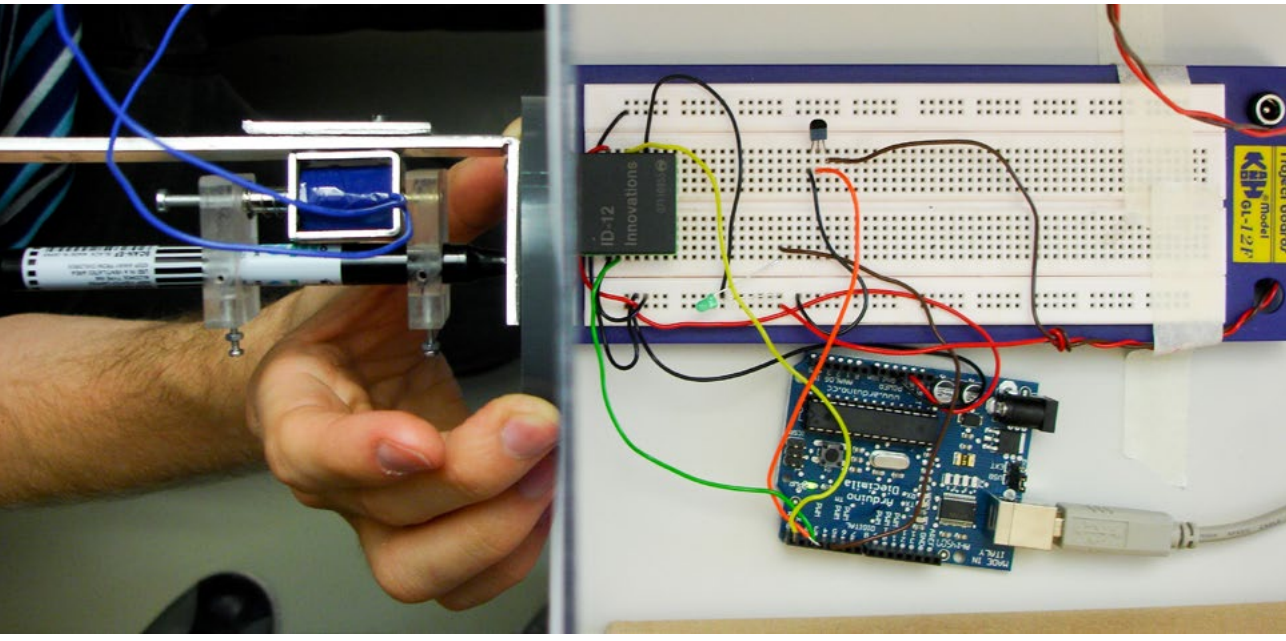

Figure 7. The RFID pen in action: the pen can be seen on the left, the RFID reader in the middle, with a sheet of paper in-between.

In building our understanding of RFID the first thing we focused on was its invisibility. We could not see the radio fields that RFID uses to form a connection between a tag and a reader. We found it extraordinary that a technology that was defined as a proximity or "touch"-based interface, had so little information about what this gestural material actually entailed. To address this, we quickly hacked together a simple probe called the 'RFID pen' seen in Figure 7 and 8. This was a simple assembly of an RFID reader, a tag, and a solenoid (an electro-mechanical component that physically moves up and down) attached to a felt-tip pen. The device was designed so that it would push the felt-tip pen onto a paper surface when it detected an RFID signal. Using this odd contraption we could trace out the area of an RFID field.

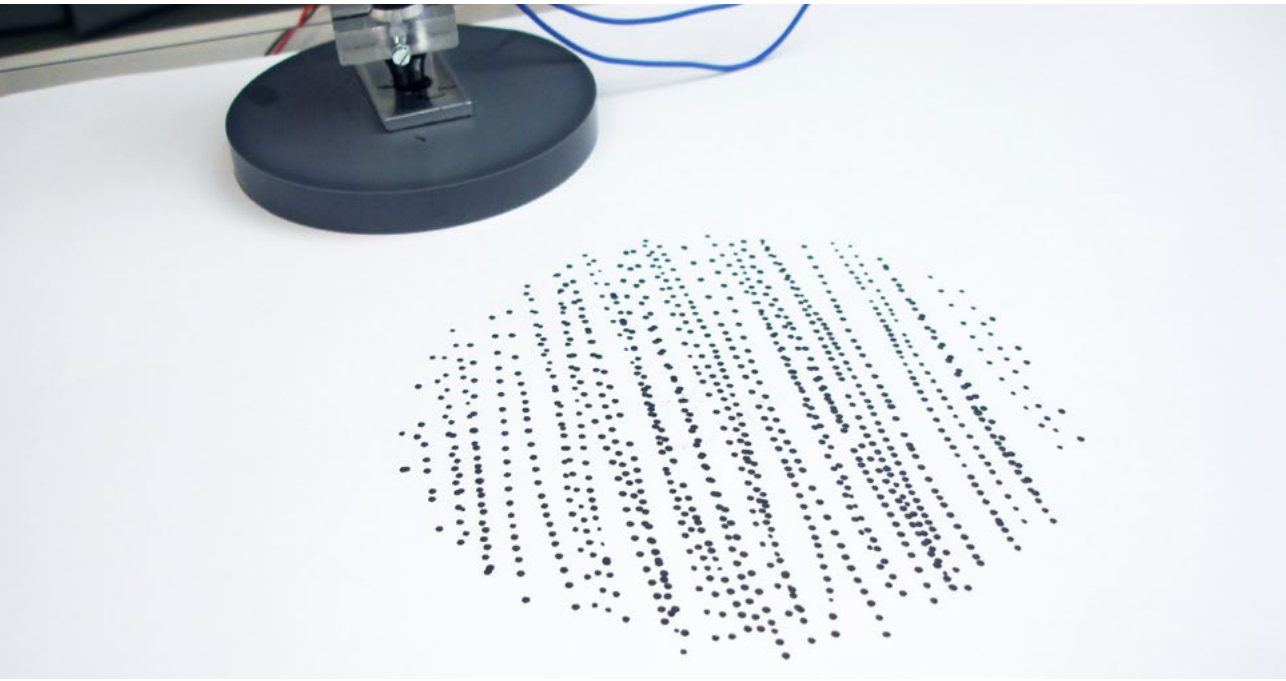

Figure 8. A drawing made by the RFID pen, the dashed area indicates the presence of an interaction between the RFID reader below the paper and the tag embedded inside the pen.

Figure 8 shows a mapping of the otherwise invisible "readable area" of an RFID system, drawn out in ink on paper. This drawing revealed evidence of the previously unseen physical phenomena of this invisible, wireless technology. Although RFID was already defined as a technology through which one could build "tangible" interfaces, it had not been conceived

of as a design material before. This drawing showed us RFID had distinct and discoverable material qualities, physical phenomena taking up space in the real world, just like plastic or wood. We began thinking about RFID interfaces as a set of interactions between these physical spaces.

The drawing represented a significant shift in our research by design approach: we had moved from researching *products* and *use* to *generating material knowledge* about the technology itself, *through visual means*. We began to see the possibility that the work of design and design research might not only be in shaping application, use and theory but in shaping our understanding of technological materials. This was the first time that I had glimpsed the possibility of using visual design processes to explore and communicate the phenomena of technological design materials.

These drawings, and the film that we made about them, alongside the subsequent films that were inspired by this experiment, added up to a body of visual, explanatory work that was used widely in teaching, lectures, keynote talks, embedded in online blog-posts and in our own design work. It was used to escape the dominant, solutionist visions of the technology and to represent RFID as a phenomena with materially bounded and perhaps non-obvious opportunities and constraints. Our work inspired others to do similar investigations, and catalysed discussion and disagreement amongst other groups of designers, engineers and marketers. Our drawings, images and visualisations ended up being used as representational symbols for RFID technology and many others in related design and technology domains took up our communicative practices to explore other aspects of technologies.

The aspects of making and visualising here also suggested *making visible* as the title of this thesis. Making visible is a literal description of our design research process, that engages in a hands-on making process in order to create visual material. It is also metaphorical, in the sense that it represents the concept of making apparent, bringing something that did not exist into comprehension. It represents a clarifying move, of revealing and explanation, as a mode of design discourse.

The mediational, material and communicative

This thesis proposes mediational materials as a central and novel concept that draws on and extends the concepts of mediation, materials

and communication. Analytically, the meanings of RFID are taking up through the concept of *technoculture* and *mediation*, material is taken up through a return to historical concepts of *design material* and *exploration*, and *communication* is taken up through the concepts of *mediation* and *articulation*.

Through the creation of this research it has become clear that these three areas have been overlooked in the transition from traditional design practices into interaction design. In graphic design for instance, the attention to culture, meaning and remediation has had a long history (e.g. Poynor 2001, Noble & Bestley 2007). The concept of material has been contested in the transition to digital design, but recent developments suggest that design material approaches can be re-evaluated as technology no longer means the immaterial nature of software and screens. Although design has traditionally been seen as a discipline focused on communication, such as in advertising or signage design, the communicative and mediational aspects of design have similarly been lost in the transition to the digital, being overshadowed by user-centred and participatory approaches, as well as being obscured by the novelty and difficulty of working with the digital medium. Mediational materials turns design's attention once again on working communicatively, in order to share understandings of design materials at multiple levels: from personal tacit understandings, to the shared knowledge of the design studio and the design community, to the shaping of the popular imagination.

Key concepts

This engagement with the materiality of technology alongside a cultural, mediational approach to design research does not easily fit into existing models of either design research or practice. Theoretically, it calls for a different framing of design research that emphasises its material, mediational and discursive qualities. To tackle this I draw on mixed methods that include socio-cultural perspectives on design (e.g Morrison et al 2010) material approaches in design research, approaches to visual culture and communication from social semiotics, and perspectives on design research from Actor Network Theory (ANT). It tackles the issues around the ways in which the "materials and media of research are also agents – they have agency – in the research process" (Lury and Wakeford 2012:18).

Design mediation

In addition to the technocultural, the concept of mediation is also central to an understanding of design. The concept, first introduced by Vygotsky

(1978) in developmental and learning research, suggests that learning is mediated by different cultural tools and signs which mediate between humans and the environment. The mediating aspects of interfaces have become a key concern for some interaction design research. For instance, for Kuutti (2009) mediation forms a central means of understanding design practices and designed interfaces. Eikenes (2010) develops the concept of double-mediation, where an interface can be regarded as both tool/instrument and sign/media:

> The interface is not only a functional tool or instrument, or a semiotic artefact or medium; as a complex and mediating artefact it must be considered to be both. (ibid:68).

The concept of *the mediational* is taken up in order to see interfaces and interface technology as part of the socio-culturally shaped meanings, understandings and uses. This is deliberately in opposition to more instrumental approaches and understandings of interfaces that are currently the dominant modes of analysis in design and engineering. Although design has traditionally seen communication as part of its fundamental approaches and outcomes, the communicative and mediational aspects of design have been under-explored as design research has instead focused on user-centred, participatory approaches on one hand, and instrumental, technically-centric approaches on the other. It is through the development of mediational analysis that we become able to see interface technology as part of its sociocultural context, as "socially shared symbolic system of signs and meanings" as it participates in the "dynamic formation of contemporary technoculture" (Balsamo 2011:5). I develop an approach to the mediational that connects the cultural and the technical through design, that is built from multiple perspectives including the technocultural (ibid), remediation (Bolter & Grusin 2000) and articulation (Hall et al. 1996).

Design material

The concept of *design material* is explored and extended in order to develop new perspectives on interface technology. Although the concept of digital materiality is problematic and has recently been contested across many design and engineering disciplines, I show that digital materials can be explored, visualised and shared as part of design research practice. The problem of digital materiality in design and engineering has been in the transition away from shaping physical materials to digital systems. There are highly persuasive themes of immateriality, invisibility and seamlessness in much Interaction Design, Human Computer Interaction and Ubiquitous Computing literature that present problems for any

material perspectives. However, recent developments in interface technology moves away from shaping software on screens, and moves towards shaping physical and tangible interfaces like RFID. This sharply brings back into focus the issues of physical materiality, and suggests that the digital can be once again understood through using design material approaches.

Drawing on traditional perspectives on design materials from Manzini and sSchön as well as more recent concepts of digital materials (e.g. Hallnås & Redström 2006) allows us to once again see design materials as central to interaction design. Manzini and Cau (1989) see material as central to the processes of design and invention, where they find that design operates at the "intersection between what is thinkable and what is possible" (ibid:17). What is thinkable is defined by models, cultural structures and forms of knowledge, but what is possible is defined by the materials of technological development. He finds that this relationship between thinkable and possible is neither simple nor straightforward:

> There is no broad, free-ranging Thinkable that has only to squeeze into the boundaries of the Possible, because the very awareness of those boundaries is a basic element of what can be thought of. (ibid:17)

Thus what is thinkable is tightly wound into the technologies and materials of design practice. In a similar manner, and from a similar period of design history, Schön defines design as a "reflective conversation with the materials of a design situation" (Schön 1983:175), where the materials "talk back" to the designer as they are explored and worked. A reflective, reciprocal process between designer and material is one of the subjects of this research; I develop processes of material exploration, that involve creatively revealing and documenting interaction design material.

Discursive design and communication

Beyond these material perspectives, this research has also opened up for extending these concepts of dialogical and material processes at different scales: from developing personal tacit understandings, to supporting shared knowledge in the design studio and the design community, to the provocation and engagement in the popular imagination. This is a central theme of the kind of communicative design research that we call discursive design. As discussed in Article 2, discursive design allows designers and researchers to place:

> mediational and discursive aspects at the center of their design-related activities when working with digital technologies and emerging situated socio-cultural practices. (Morrison & Arnall 2011:233)

In discursive design, "the emphasis of design research is on communication." (Arnall & Martinussen 2011:120) in which the outcome of a design process can be to "broaden the context of public technology discourse and interaction design research with technology." (ibid:119). As Morrison and Arnall (2011) point out:

> the object of discursive design analysis is communication informed by research and developments in social semiotics and multimodality, as well as from more technical domains, we would add, such as ubicomp and Human Computer Interaction (HCI). (ibid:226)

In its communicative focus, discursive design closes the loop in Figure 9, below, where it allows us to see interaction design as a way of discursively mediating between technological materials and culture. In summary, the key concept of mediational material focuses attention on the central communicative practices in interaction design, in order to discursively explore, develop and share understandings of technologies as design materials. Next I turn to the approaches and methods of this study.

Design research approach and methods

The thesis is composed from a blend of both research methods and design methods that can be called 'research by design' (e.g. Fallman 2008, Sevaldson 2010). It is mixed methods research that explores the subject matter through the use of multiple exploratory and investigative perspectives. This pragmatic approach to research, through its pluralism and eclecticism in methods (e.g. Johnson & Onwuegbuzie 2004), aims to provide a rich account of a complex and rich design practice.

The subject of this research is drawn from at least three dynamic and emerging fields of study, mainly design research, ubiquitous computing and Human Computer Interaction (HCI). The research approaches are gleaned from methods in design research, visual culture, communication design and the digital humanities that are explored in Chapter 2. These perspectives and approaches necessarily emerged from a trans-

disciplinary research by design process that involved a diversity of participants, from ethnographers to engineers and designers.

The research and design approaches developed in this thesis have been exploratory, creative and generative, conducted around an area that has not been clearly defined. I build knowledge through making and reflecting on this action of making and communicating. In this exploratory research the practices I develop, and the phenomena I encounter, challenge us to describe and rescript the themes of invisibility and seamlessness in technology, and the nature of mediation in design.

The discursive approach to building knowledge that is elaborated here involves three closely-linked approaches, each with their own modes of analysis and production:

1. The study of the existing visual culture of RFID interfaces through images, symbols and media representations of the technology as semiotic mediations (e.g. Kress 2004, Eikenes 2011). This work built a body of visual material in the form of shared image archives.

2. The exploration of RFID as a design material, drawing on concepts of design materials (e.g. Bucciarelli 1994, Manzini & Cau 1989, Fernaeus & Sundström 2012). RFID interfaces were analysed, probed, deconstructed and reproduced in order to generate new knowledge and understanding of RFID as a material phenomena.

3. The communication of this material phenomena of technology through visualisation methods in photography, film and animation. This focuses on visual explanations (e.g Henderson 1999) of the technology that engage and intervene in visual culture by visualising, mediating and communicating these invisible phenomena.

Together these three approaches support the creation of an account of RFID technology that stems from, and is situated within, existing technocultural discourses, but that challenges these through new material understandings and new kinds of visual mediation. The analysis, engagement and reflection on RFID technology is developed as an account through material and communicative means. This is a design-led process that is productive as well as interpretative: it produces new material knowledge as well as providing a reflective analysis of this production.

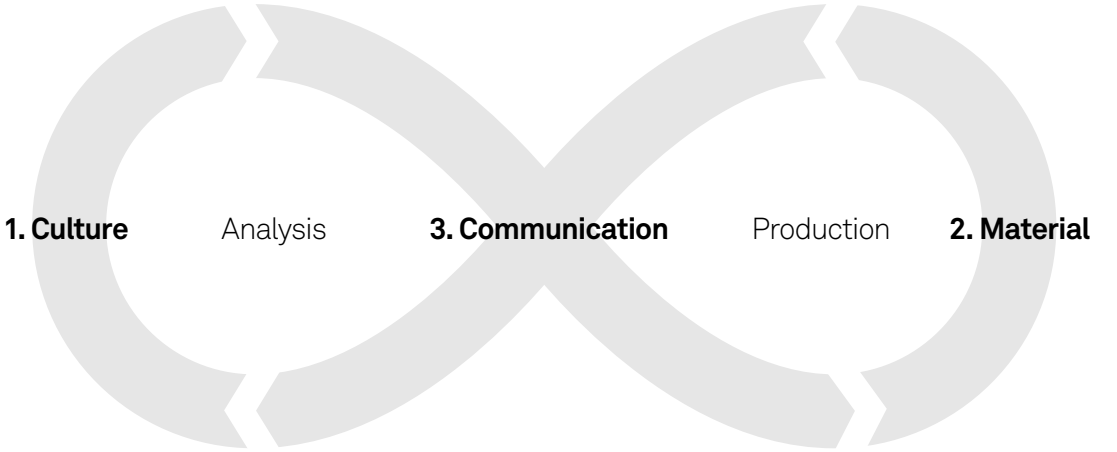

Figure 9: A model of the related approaches involved in exploring mediational materials.

I have developed an abstraction of these interlinked elements in the shape of a model that shows the related approaches that are expanded in chapter 3. The model shows the two domains of technoculture: 1. the cultural and 2. the material that are linked through 3. analysis and production of communicative material. I propose that this intertwined process of cultural analysis, material making and production of communication is a central practice for design research that works towards shared understandings of technoculture. I unpack this claim in the articles included in the thesis, and further below in this exigesis.

Unpacking the three approaches

What follows is an outline and introduction to the three approaches and how they are framed and explored throughout the following chapters.

Approach 1: Engaging with RFID as a technocultural phenomena
The first approach of the three is an engagement with the shared symbolic, mediations, meanings and signs in technology and interfaces. How does design research take up the understandings, mythologies, expressions and knowledge already in circulation about a particular device, technology or interface?

An understanding of culture is an often overlooked yet important aspect of interaction design. As Balsamo (2011) states, it is "no longer

tenable to cordon off the study of technology and innovation from the study of culture." Technologies are truly post-disciplinary, disrupting and challenging practices across commercial and academic domains. Interfaces and interface technology in particular have moved from being specialist, technical concerns to become culturally significant and potent. We no longer talk about interfaces as just utilitarian tools, they are playful, social, critical. They now have genres, audiences, materials and medium (e.g. Murray 2012).

I take up the study and analysis of technoculture as the first approach because it helps frame a culturally-inflected kind of design research, and rhetorically it enables us to look at RFID as a cultural phenomenon. Balsamo more specifically defines technoculture as the "performance of two critical practices: 1) the exercise of the technological imagination; and 2) the work of cultural reproduction" (Balsamo 2011:6). The exercise of the technological imagination is the "development of new narratives, new myths, new rituals, new modes of expression, and new knowledges that make the innovations meaningful" (ibid:7).

Balsamo further sees the technological imagination as a "complex process of meaning-making whereby both technology and culture are created anew." (ibid:7). This is important as it places design as a cultural activity rather than simply a problem-solving one, where designers are involved in the creation and articulation of meaning and mediation. It also helps situate design as a practice that does not simply invent out of thin air, but involves the engagement, remediation and reproduction of existing practices and cultural phenomena, in what Balsamo calls "cultural reproduction". This is the understanding that an innovation "must draw on understandings that are already in circulation within the particular technocultures of users, consumers, and participants" (ibid:10) Through this framing of technoculture, Balsamo suggests that culture is both a resource for, and an outcome of, the designing process.

In this thesis, existing RFID interfaces are studied as semiotic mediation through observation, photography and filmmaking. This approach observes and makes sense of the visual mediation of technological phenomena on order to pose questions about how it is interpreted. By focusing on these various representations and understandings, in a humanistically oriented view on interaction design materials and mediations, we can generate knowledge about how the technology is situated, understood and imagined in its cultural context.

Figure 10: Advertising for London's RFID-based Oyster Card. The concept that physical money is 'slower, messier, pricier' and that RFID-based ticketing is 'faster, smarter, cheaper' encapsulates the commercial perspectives on the technology.

RFID was chosen as a technocultural phenomena to study because it articulates a number of different perspectives. These include intense research interest and industrial development, everyday use, folk mythology and dystopian tropes from popular media, alongside powerful, spectacular and persuasive marketing. RFID is a technology ripe with existing discourse, argument, controversy, while simultaneously being used by hundreds of millions of people every day. As the billboard in Figure 10 shows, RFID is seen as a way to make transactions in complex systems such as transport more efficient and less "messy" than physical coins. Research into RFID interfaces is mainly situated in HCI and ubiquitous computing contexts. A design-centric, critical, cultural,

material-focused analysis of RFID technology itself is not yet the subject of much research.

The invisible nature of RFID's radio communication is the cause of much of the excited anticipation, debate and controversy around the technology. Digitally identifying an object at a distance is envisioned to have implications for robotics, automation, and building an "internet of things", a vision of a future where connectivity and identification is embedded in everyday objects and environments.

Ubiquitous computing is a vision that "proposes a digital future in which computation is embedded into the fabric of the world around us." (Dourish 2004b:1). RFID is a prototypical 'ubiquitous computing' technology in two distinct ways: 1) it forms the technical and conceptual foundation for much ubiquitous computing research, as well as 2) it has been embedded into the practices and environments of everyday life for many people around the world. The contemporary rhetorics of ubiquitous computing propose *invisibility* and *seamlessness* as a desirable quality of interfaces. Seamlessness emphasises the "deliberate "making invisible" of the variety of technical systems, artifacts, individuals and organizations that make up an information infrastructure." (Ratto 2007:21). In disappearing into everyday objects and environments RFID is seen as an enabler of Weiser's (1991) visions of calm and "seamless" computing experiences.

The marketing of RFID involves themes of efficiency, total control, frictionless capitalism and security. RFID is marketed as being more convenient: a "tap" or a "swipe" rather than a cash or mechanical credit card transaction, or as the ability to check an entire warehouse for inventory from a distance. RFID is envisioned in a manner that in urbanism is pejoratively called "solutionism" (Dobbins 2009), where solutions to large societal problems are envisioned through the use of grand technological schemes or gestures in a way that is highly disconnected from their material and social reality.

Figure 11: FoeBuD's 'Stop RFID' campaign uses both an image of an RFID antenna and the international standard 'Stop' sign to protest against RFID technologies.

These future-oriented, speculative "envisionings" of RFID technology have in turn generated fear of the technology and protest. They have led to spectacular dystopian visions, misunderstanding, folk-mythology, fear, uncertainty and doubt. Films such as "The Catalogue" (Oakley 2004) depict daily life in a shopping mall where every person and object is overlaid with identifying information. The commercial use of RFID is of particular concern to privacy and consumer advocacy groups who have mounted fierce campaigns (such as Figure 11) and written books (Albrecht 2006) against the proliferation of RFID in consumer goods. These protests centre around the ability to embed RFID tags invisibly into everyday objects and potentially track people and their possessions (Rieback et al. 2005). Many of these protests however react to speculations and marketing material and are then at least two steps removed from

the material realities of the technology itself. This is not to imply that these concerns are not justified, but that by being distanced from the technology while involved in debates about speculative futures, the effectiveness of that critique may be impaired.

Approaches to understanding these complex, messy and inter-disciplinary issues could be gleaned from many places, including critical ethnography, visual culture studies, or ANT and Science and Technology Studies (STS) that offer approaches to the study and analysis of existing systems, technologies, social constructs and visual culture. Yet, what is missing in these approaches though is an account of the generative aspects of constructive design processes in producing these interfaces. How have engineering and design practices engaged with existing visual culture in order to explain or to conceal aspects of these interactions and systems? How have designers taken up existing visual culture, such as advertising, instructional design and signage, in order to design new kinds of RFID interfaces? The linkages between visual, cultural analysis and the generative processes of material exploration and communication design are explored in chapter 3. Next, I move from the mediation to the material of RFID technology.

Approach 2: Exploring RFID as a design material

In this second of the three approaches I focus on the ways in which design research can participate in revealing and demystification of technological phenomena. Interaction design is already involved in shaping user-understanding of technological products in commercial settings (e.g. Hjelm 2002), and has theory and practice for contributing to the mythology around technological development such as critical design (Dunne 1999). However there is little research in interaction design into the investigation and exploration of technological phenomena as design materials. Design materials have long been a theme within design research (e.g. Manzini & Cau 1989) yet design research has yet to fully account for digital materials. Design materials have also been overlooked under the momentum of user-centred doctrine, where user-centredness and participatory design practices have taken the centre stage, to the exclusion of research into materials.

As interaction designers engaged in understanding, shaping and communicating with technical systems we must be concerned with emerging technologies like RFID, and treat them as new "design materials" that form one of the foundations for the kinds of products and services we design. Although this sounds like common sense, an approach to technology as design material is hard to find in design research. As

Nordby (2011) pointed out in his research in the Touch project, there is a significant challenge for interaction design to understand and use new technological materials. Materials are central to design practice, and they "are a tool for inspiration as well as production" (ibid:91). Long before interaction design existed as a discipline, Manzini argued that materials, including digital and interface technologies, are under such rapid change that there is a widening gap between them and their cultural understandings (Manzini & Cau 1989).

Traditionally, interaction design has treated its design material as code or software which has led to for instance Löwgren and Stolterman's (2004) definition of the computer as a 'material without properties'. Although software and code allow for spatial and temporal fluidity in the behaviour of computing systems, there are at least three reasons for moving away from this definition of interaction design material. First, as Vallgårda and Sokoler (2010) have argued, looking at computation as a design material, with specific properties that can be shaped as part of a 'formgiving' process, is useful for theory and practice in interaction design. Second, information systems can be seen as intrinsically material, from the physical switches and infrastructures of networks, to the heat given off by processors and the spinning of hard disks (Blanchette 2011). Third, the 'material move' in interaction design, identified by Fernaeus and Sundström (2012), finds that the move from screens to tangible interaction is reinforcing the need for material perspectives, and means for material exploration and communication.

There is a so-called "material turn" across many disciplines, which can also be seen in HCI and interaction design, for instance by Dourish and Mazmanian (2011), Belenguer et al. (2012), Eriksen (2009) and Jung and Stolterman (2011). In information technology Vallgårda and Redström (2007) and Vallgårda and Sokoler (2010) explore the concepts of physical and digital materials. Further, in other disciplines, material perspectives are increasingly being used as analytical perspectives, such as in informatics (e.g. Blanchette 2011), in communication studies (e.g. Leonardi 2010), in media studies (e.g. Fuller 2005), in software studies (Kitchin & Dodge 2011), and in organisation and management studies (Leonardi & Barley 2011, Orlikowski 2010).

These analytical developments are timely, as there is a pressing need to account for the increasing complexity, invisibility, abstraction and normalisation of technology-mediated experience. The disappearance of interfaces, driven by wireless and embedded technologies such as RFID, has led to a loss of agency in the design of technological devices

due to lack of understanding and control over technical materials. The overwhelming complexity of networked, computational systems have also hindered critique of their development and hampered constructive experimentation.

In this thesis I pursue the problem of invisible and immaterial qualities of RFID technology. Previously the subject of science-fiction, the blending of the physical and the digital was for a long time the subject of rarefied ubiquitous computing research. But now "we now inhabit the future imagined by its pioneers" (Bell & Dourish 2007), and we live alongside, and must design with, these increasingly invisible concepts and phenomena. Hjelm (2005) describes invisibility as a significant issue for ubiquitous computing in that it creates the problem of "double invisibility" where:

> invisible computer technology appears as a way to normalize, naturalize, and reify computer and information technology. The invisibility creates a power position where it is nearly impossible to criticize or change the prevailing system. (ibid:78)

Indeed, there are multiple, layered forms of invisibility and materiality that may be addressed by any exploration or critique of RFID technology. The objective of material exploration is to question and explore the technical discourses that surround an emerging technology. In the case of RFID, it can be taken up to question the concepts of immateriality, invisibility or seamlessness that are part of the imagination of its technical potential.

Before proceeding, I will briefly provide a little more detail on RFID technology itself.

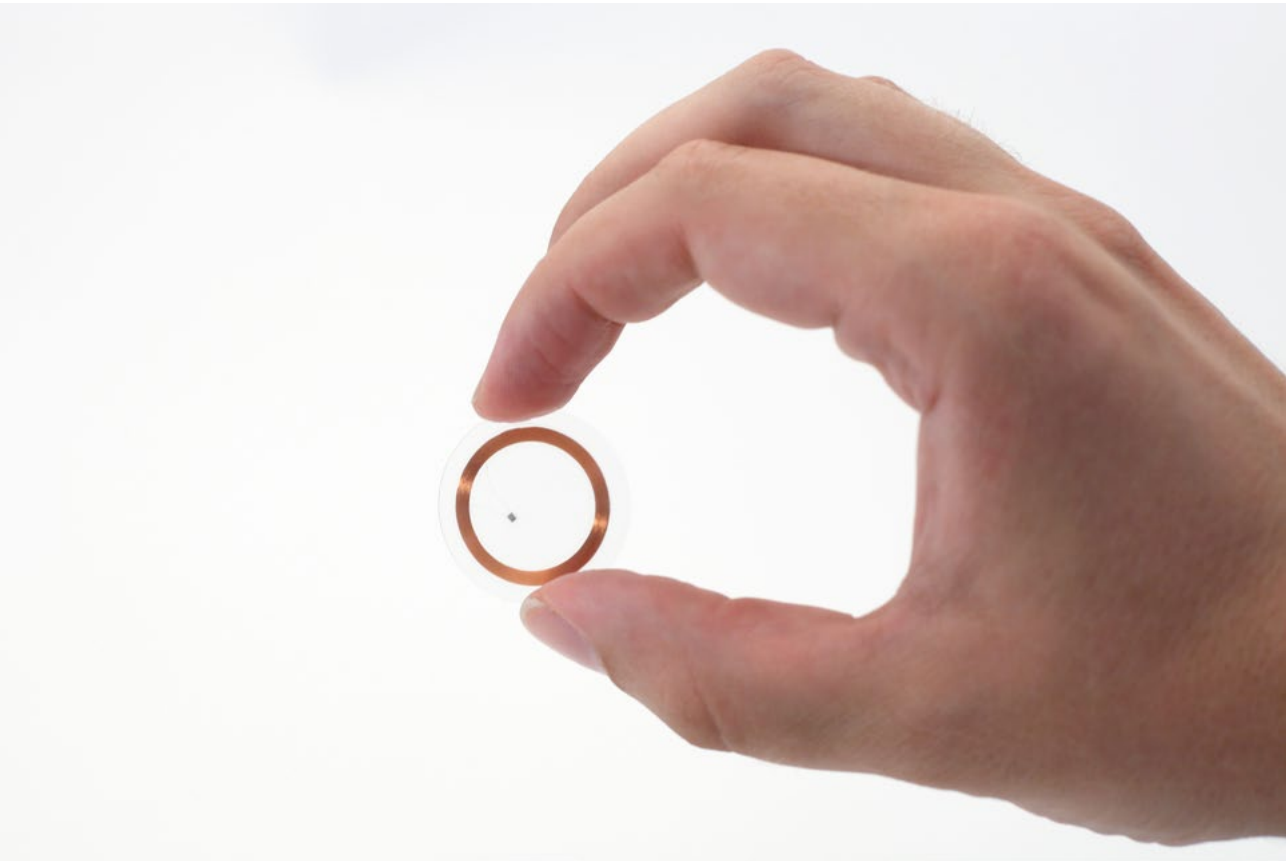

Figure 12: A common, low-frequency RFID tag, the circular elements are a coiled antenna, the tiny circuit (black dot) in the centre contains a unique identifying number.

Technically, RFID refers to a wide variety of technical means of transferring data between small, battery-less chips (a 'transponder' or 'tag' such as the one shown in Figure 12, above) and a powered interrogating device (a 'reader' such as the ones shown in Figure 13, below).

Figure 13: A collection of RFID readers, showing that readers can be embedded inside many different kinds of powered devices, including mobile phones, SD cards and USB dongles.

There are many varieties of standards, applications and technical realisations of RFID, each of them with particular specialist applications that define their particular material properties and their technical and physical feasibility. From a cultural and media history perspective Rosol, (2010) offers us a glimpse of the many applications of RFID technology:

> there are contactless smartcards to exert access control, there are passports with tags embedded for electronic authentication, bold tags placed in windshields for electronic toll collection, tiny tags implanted in cows and pets, there are tags put on books in libraries, other tags used for inventory management, special tags employed for pallet tracking, a different kind of tag again employed in the aerospace industry to fight counterfeiting,

> proximity-tags in cellphones to allow for so-called "Near Field Communication," and last but not least, there are self made tags employed in artistic or experimental installations to show the potential of RFID as a locative medium. (ibid:40)

RFID is now the subject of industrial, policy and regulatory attention where it is seen as a driver of economic or political change (e.g. Srivastava 2005, Hof 2007, National Retail Federation 2004, European Union 2006). As an interface RFID has been explored and developed through HCI and ubiquitous computing research, where it is seen as an instrumental tool for creating more efficient and usable interfaces (e.g. Valkkynen 2007, Hang et al. 2010, Buettner et al. 2008, Måkelå et al. 2007, Kindberg 2002, Ailisto et al. 2003, Riekki et al. 2006, Carvey et al. 2006). RFID has also received critique and scrutiny by academics, activists and media artists (e.g. Poole et al. 2008, Albrecht & McIntyre 2006, Rieback et al. 2006, Medosch 2006).

The development of RFID occurs in highly technical settings, through engineering practices that specialise in developing and optimising the performance of systems through designing antennae, signal processing systems and the microprocessors that control this hardware. These engineering practices respond to the needs of marketing or industrial competitive pressure by focusing on increasing efficiency, decreasing cost, and implementing security e.g. (Sarma 2001, Garfinkel & Rosenberg 2005, Piramuthu 2006, Engels & Sarma 2002, Ranasinghe et al. 2004, Juels et al. 2005).

In technical development processes the complexities of technology are necessarily modularised and abstracted into higher level systems of control and organisation. This abstraction allows for components to be addressed through relatively simple, high-level commands, an RFID reader for instance might have only eight pins that are used to communicate with other hardware components, each with a specific and relatively simple purpose. But what about the decisions, assumptions and material constraints that have been hidden below this abstraction? This of course still affects the way that RFID functions as an interface. If we treat those eight pins as our design material, we may be able to control the device as its engineers intended, but what if we want to use it for something outside of its intended application? Or what if we want a very nuanced understanding of the radio field it produces? The component's data sheet might only be a couple of pages long, hardly a rich description of RFID as a technical 'material'.

In this thesis I suggest that RFID can be explored through design processes of making and material investigation, as a form of critical practice to reveal its qualities and phenomena. Material exploration is a term introduced by the design consultancy BERG in its work with the Touch project. It is an exploration of the material of a design situation, in order to build knowledge about material potentials and constraints. This is particularly important for interaction design working with emerging technologies or other immaterial things like data-sets that may be unique or previously unexplored. In order to design we must have an understanding of our materials, and without these kinds of explorations we risk making assumptions or relying on folk-mythology about the affordances and constraints of a particular interface technology.

Through processes of making and material explorations we built a technical literacy, describe and unscript the material itself, in order to reinscribe and reposition it. These material-centric approaches are a way of grounding the technological imagination in the actual phenomena and constraints of technical systems. This kind of exploration takes place in a co-design context, where the knowledges and skills of engineers, technologists, researchers and designers are brought together in the investigation and interpretation.

RFID technology has definite physical, material qualities in its radio field, and interactional qualities that define how it can be used as a part of interactive systems. These qualities and the visual representation of these qualities is taken up in existing interface culture in Chapter 2 and as a design exploration in Chapter 3. In Chapter 4 I propose that in addition to understanding software as a material of design, and beyond the material perspectives on organisations and design practice, we need a material practice that can investigate, describe and re-imagine emerging tangible interface technologies like RFID and sensors that have inherently physical, material properties and qualities.

Next I describe how these technical phenomena might be translated and communicated in order produce work that negotiates and transforms the meanings of RFID as part of a shared technocultural imagination.

Approach 3: Mediation and communication of RFID

The third approach is both production and exploration of RFID interfaces as *communication*. A focus on communication emphasises the exploration and analysis of RFID through its cultural, communicative, mediational qualities: its symbols, mythologies and meanings as described in approach 1 above. However, communication is also central to the

production of new perspectives on RFID, through icons, visualisations, photography, films, alongside new interfaces and interactions created in the approach above. It is through a sensitivity to communication that design research is able to participate in the wider discourses about RFID. This is a means for design research to engage in the processes of shaping the technocultural imagination by taking existing meanings and cultural phenomena and remediating them into new interfaces and new cultural, communicative artefacts.

Design projects typically have to develop and align a wide variety of knowledge and practices in their processes and production. Interaction designers for instance may combine technical knowledge with understanding of user-behaviour and practices of information organisation and communication to work towards a proposal or prototype. As pointed out by Ewenstein and Whyte (2009), designers simultaneously use a range of visual representations from sketches to photography and videos that are meaningful in different ways to different audiences and stakeholders. It has been argued that the visual plays a significant role in the emergence of digital technologies, and that this gives design a central role in this process (e.g. Kress 1998, Shields 2002, Smith 2009, Cubitt 2002).

Visual practices have "an essential mediating and structuring role in the negotiation of design decisions" (Klopp 2010:1). They are the 'means' by which power is concentrated and mobilised in design, with great effect on the cultural and social relations of those who engage in them. These effects are not neutral, they can cause unproductive relationships, friction and disempowerment between disciplines and groups. As identified by Klopp, visual practices empower designers in a number of ways, in particular through the specialist ways in which they can produce, manipulate and interpret visual representations. By working with visual representations of technologies, then, through their symbols and meanings, designers have to contend with the power of visual practices to shape the development and perception of an emerging technology.

Communication is a central theme in interaction design, where communicative approaches have been discussed for instance by Mullet and Sano (1994) who were concerned with the mediating qualities of early graphical interfaces. Crilly et al. (2008) investigate the various models of communication between designers and users through artefacts, drawn from studies of design research. Maier et al. (2005) attempt to address different ways of conceptualising communication in engineering design, for instance seeing communication as the co-ordination of behaviour

in product development networks. From an ethnographic perspective, Roschuni et al. (2013) looks at the role for communication of user-research in design.

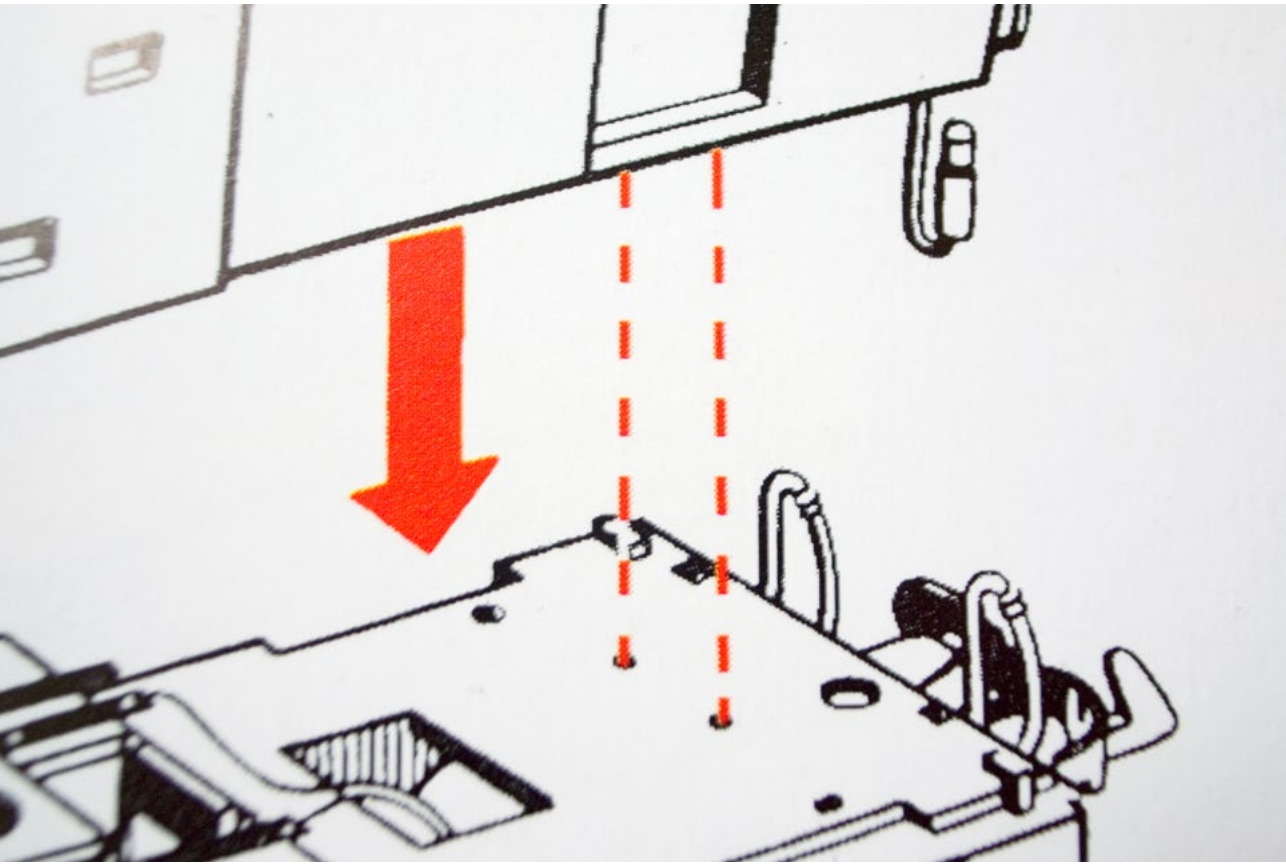

Figure 14: Instructional drawings are often required to explain the use and function of technical objects, creating visual conventions such as the dashed line to represent movement, hidden geometry or borders.

Design has a long history of shaping visual representations and meaning and in engaging in collective, popular, cultural understandings of the technical world, through such specialisms as instructional design (such as Figure 14), signage design, advertising, graphic design, even propaganda (e.g. Mollerup 2005, Mijksenaar & Westendorp 1999, Baines & Dixon 2003, Mijksenaar 1997, Poynor 2001). Social semiotics is a means to analyse the meanings and interpretations of these various visual representations, through a focus on the text (in the broadest sense

which can include speech, writing and images as different "modes") and the readings of that text. Eikenes (2010) in particular develops the notion of "semiotic mediation" in visual interfaces; "how meaning is embodied in the interface in a social and cultural context." (ibid:67). He notes that interface designers may draw on semiotic resources "from a range of media types, including television, physical products, magazines, books, cinema, and other interfaces." (ibid:87) and that the interface must be understood in relation to other texts. In other studies of design, Djajadiningrat et al. (2004) takes up the semiotic, communicative qualities of tangible interfaces, Karana et al. (2009) takes up the meanings in industrial design materials, You & Chen (2007) compares affordances with symbols in products and Hjelm (2002) looks at how semiotics can be used to understand communication in product design.

In this thesis, RFID interfaces are treated as instances of semiotic mediation, the layers of signs and signification that work alongside the instrumental, tool-like qualities of an interface. By following Eikenes (2010) and analysing and designing RFID as semiotic mediation, where interfaces are treated as sign or semiotic artefacts, we are able to conceive of them as situated in specific historical, cultural and social contexts. By seeing interface technology as mediational, we set the stage for analysing how design intervenes in understandings and meanings of technology in culture.

By looking beyond the mediation of direct experience, of an RFID interface in use, towards representations and articulations through cinematic, audio-visual and social media, we can situate interfaces and emerging technologies in their cultural contexts. By recognising that mediation through images, film and other forms of media (and particularly online media) shapes a significant part of our imagination of technology and interfaces, we shift the emphasis of interaction design research away from functional and user-centric perspectives. This suggests a new role for interaction design research, that rather than designing interfaces for use, instead intervenes in the popular cultural imagination through analysis and production in these semiotic mediations.

When taken together this discursive design practice aims to contribute towards a shared cultural and material understanding of RFID in interaction design research, and related to other design, technical and cultural communities of practice. There is an opportunity then for RFID technology to be taken up in design research in order to be understood as a communicative, mediating, cultural phenomena already filled with

meaning, and with much potential for new meanings and mediations. Further, it points towards a kind of communicative design research practice that can be used more broadly to analyse and intervene in emerging technological change.

The type, outline and summary of this thesis

Type
This thesis consists of a compilation of four peer-reviewed articles, that are gathered together with this exegesis. These articles span a period between 2011 and 2013 and were created in collaboration with colleagues in the Touch project. The four publications form the core of the reflection on the design practices, while this exegesis offers discussion, explanation and analyses of the approaches and the theoretical context.

Outline and summary
The thesis is structured around the three interlinked approaches to analysis and production detailed above, each of which contain theoretical and practical concerns. These three approaches are then expanded and discussed through four chapters. Each chapter is organised around the three central approaches: culture, material and communication. In the table below you can see these areas as they play out across the thesis.

Chapter	Culture	Material	Communication
1 Introduction	Intro to technoculture, design and RFID	Intro to design material	Intro to communication
2 Background & Contexts	History of interfaces, RFID and interface culture	Defining design material and exploration	Mediation, communication, visualisation and media
3 Approaches	Exploring technoculture	Material exploration of RFID and further wireless interfaces	Creative communication design
4 Reflections & Conclusions	Reflections on technoculture	Reflections on material	Reflections on discursive design

The first three chapters provide an overview and context for the research, providing a reflection on the themes in the four published articles. Chapter 1, the introduction, provides an overview of the

practical, theoretical and contextual concerns. In Chapter 2 the practical and theoretical background for invisible interfaces, interaction design materials, visual communication and mediation and are outlined and discussed. In Chapter 3 the material and mediational design approaches to invisible RFID interactions are developed. In Chapter 4 reflections and conclusions are presented. Following this the four published research texts are included.

The following research questions are addressed in the articles:

Article 1: Exploring 'immaterials': mediating design's invisible materials
In this article I explore how a designer might explore an invisible interface technology like RFID, in order to have reflective conversations with it as a design material. I also inquire into how material and mediational approaches contribute towards shared knowledge of RFID, both in design and as a means of discussion across disciplines. This article problematises the drive towards invisibility and seamlessness in the dominant approaches in design and technology. It does this by taking up a communicative design approach that makes visual material out of RFID technology.

Article 2: Visualizations of digital interaction in daily life (written with Andrew Morrison, 2011)
In this article we inquire into how visual signage may make aspects of ubiquitous computing technologies visible and how digital tools and platforms impact that visual design and semiosis. This article takes a discursive, sociocultural view of emerging digital interaction in public spaces, by analysing their visual, interactional and persuasive qualities.

Article 3: Satellite Lamps (written with Einar Sneve Martinussen & Jørn Knutsen, 2013)
This online article explores how interaction design practice can take part in gathering insight and creating meaning in the meeting between new technologies and everyday life. It offers reflections on how on interaction design practice can works towards understanding and communicating about the Global Positioning System (GPS) in a sociocultural frame as material, history, technology and as design.

Article 4: Depth of Field: Discursive design research through film (written with Einar Sneve Martinussen, 2010)
This article explores how designers might use and shape audiovisual media to support processes of understanding and conceptualising with emerging technology as part of their practice. What opportunities do

audiovisual media open up for design in explanation and communication of interface technologies within a broader social and cultural context? This article analyses the use of narrative and audio-visual material to communicate about RFID technology through design research.

This order was not the chronological sequence in which these articles were published, but this order builds an argument from the materials to the mediation, that is central to the thesis.

Summary

In the journey towards understanding the way that interaction design may intervene in the technocultural imagination of RFID I have developed practical and analytical concepts and approaches. In this chapter I have offered a brief introduction to the context of contemporary interfaces including RFID, to the ways in which this research was instigated, the key concepts and the three approaches that were developed. They key concept of material mediations that draw on the combined histories of design materials and the communicative, visual, mediational aspects of design research form the central frame of the thesis. These are unpacked more fully in the next chapter.

Chapter 2
Background and Contexts

In this chapter I outline some of the background and context to design and research with RFID technology. I begin by looking at perspectives on designing technoculture, that brings together culture, technology and the ways in which they relate through design. Then I look at the dominant cultural and disciplinary perspectives on RFID technology such as the research perspectives of seamlessness and invisibility, industrial perspectives of hype cycles, control and efficiency, and the popular cultural understandings including the fear and uncertainty caused by invisibility. Second, I take up RFID as a technical material, how it is seen as a prototypical foundation for the future of interface design, and how HCI, design and engineering approach technology as a material. Third, I take up communicative and mediational perspectives on interface technology and how we may see technology through models of communication, and the lens of media, visual culture, cinema and advertising.

As research by design, the thesis has been practice-led, and as such, it did not emerge from a dominant research perspective. This exegesis and the articles have been written alongside or after the design work, as a way of exploring and reflecting on the practice as design research. The background and context includes a necessarily broad set of disciplinary perspectives, inspired somewhat by Barad's problematisation of research where "The cordoning off of concerns into separate domains elides the resonances and dissonances that make up diffraction patterns that make the entanglements visible." (Barad 2012:2). In order to reflect the richness and trans-disciplinary complexity of the design work, I have explored a number of theoretical perspectives. These are drawn from Human Computer Interaction (HCI), ubiquitous computing, interaction, communication and critical design, as well as socio-cultural and humanist approaches from the digital humanities, media studies, Science and Technology Studies, learning and development theory.

What follows is an exploration and an explanation of these related perspectives. They are used to explore the relations and entanglements between this work and research in other fields, to build a broad basis for analysis of the design practice. These foundations provide a means of gaining perspective on each of the three areas in the model in Figure 9.

Designing technoculture

How does interaction design engage with both culture and technology? Design has a long history of shaping the relations between technology and culture, through creating objects, typography, graphics and interfaces used by millions of people. One might then expect a strong theoretical foundation for understanding how design deals with both technology and culture, yet it is very rarely seen through these perspectives.

Design research is most often dominated by prescriptive, normative and technical frameworks that attempt to define design as a 'problem solving' activity, outside of cultural or social contexts. The development of technical objects is perhaps most often seen as a process of diffusion from invention to adoption in society. This perspective relies on the idea that a technology has intrinsic properties that enable it to become widespread in a socio-technical environment. Instead, Akrich et al. (2002) see innovation happening as a model of 'interessement' which "sets out all of the actors who seize the object or turn away from it and it highlights the points of articulation between the object and the more or less organised interests which it gives rise to." (ibid:205). This perspective forces a consideration of technological and sociological analyses together, in an attempt avoid treating the properties of technologies and its social effects as separate categories.

In his analysis of the cultural construction of Edison's motion picture technologies, Carlson (1992) challenges the idea that invention can be seen as an act of problem solving. Instead he proposes that scientists and inventors construct "both nature and explanations of nature" (ibid:69), that inventors invent both artefacts and frames of meanings in which "success comes from interweaving the social and the technical in ways that make it impossible to unravel and separate the two." (ibid:176). The term 'frame of meaning' is drawn from Collins and Pinch (1982), and is used to analyse how technologists draw on their larger culture to create perspectives that guide their invention activities: the design of artefacts, and the manufacture and marketing efforts of bringing an invention into the world.

Balsamo (2011) argues that technology is rarely addressed as a cultural phenomena, and that the cultural aspects of innovation are often lost underneath the technical. In this narrow perspective we often are faced with the conditions where

> technological failures are attributed (in a most unsatisfactory manner) to both unintended consequences and unforeseen circumstances. Continuing to bifurcate the technological from the cultural not only makes probable consequences unthinkable, but also severely limits the imaginative space of innovation in the first place. (ibid:4)

Instead, Balsamo follows Slack and Wise (2005) and avoids setting culture and technology in opposition to each other. By formulating the unity of 'technoculture' she seeks to "extend the questions, methods, and analytics of cultural studies to the disciplines and domains of human practice that are centrally engaged with technological innovation." (Balsamo 2011:5). In 'Designing Culture', Balsamo is interested in the practices of meaning making in design, and how the "meanings of new technologies are reproduced, structured, manipulated, hijacked and sometimes contested." (ibid:49). She redefines design and innovation as a process of the technocultural imagination and of technocultural reproduction. First, the technological imagination is:

> a mindset and a creative practice of those who analyze, design and develop technologies. It is an expressive capacity to use what is at hand to create something else. [...] It enables a person to understand the broader set of forces that shape the development of new technologies and take account of how these forces might be modified or transformed. (ibid:31)

In the second of her principles, technological reproduction, she proposes that "Designers serve as cultural mediators by translating amongst languages, materials, and people" (ibid:11). This is not only the reproduction of technical elements such as codes, forms of knowledge, standards and conventions, but that cultural reproduction is an articulatory and performative process:

> To be comprehended, an innovation must draw on understandings that are already in circulation within the particular technocultures of users, consumers and participants: at the same time it must perform novelty through the creation of new possibilities, expressed in the language, desire, dreams and phantasms of needs. (ibid:10)

Balsamo cites Klaus Krippendorf who describes one of the fundamental paradoxes of the designing process as an oscillation between "the aim of making something new and different from what was there before, and

the desire to have it make sense, to be recognizable and understandable." (Krippendorf 1995:156). So the work of design is then an exercise of the technocultural imagination, that requires knowledge of previous articulations of technologies. It seeks to understand the meanings and signifying elements in existing articulations of technologies, and to use those meanings and materials in order to create something new.

However, in many studies of technology and culture, from cultural theory, social semiotics and Science and Technology Studies for instance, the analyses of design often come after the fact, as post-analyses of finished design objects or systems and their meanings, scripts and relations. As Shove finds "designers rarely figure in sociological or anthropological analyses of material culture and value." (Shove et al. 2005). As examples of these after-the-fact analyses of designed objects we can look at for instance the 'multimodal analysis' of the iMac and Dell Computers by Riley (2003) or Yaneva's (2009) analysis of everyday objects such as the door lock and Folkmann's (2011) exploration of cars, various 'critical design' objects and the Sony Walkman. These analyses take a view of design as a noun, a kind of design that is about objects (a chair, a lock, a computer) and their associated meanings.

What about accounts of design as a verb? What is required is an account of the designing of technical objects as a cultural process, of designed objects as complex, culturally resonant compositions of materials and mediations that are shaped as part of design practice *and* analytical research. How do designers take up existing signs and symbols and use them to participate in cultural production as part of the act of creation and invention? How is culture and technology folded into design work and invented with? And how might playing and inventing with culturally resonant images be taken up by designers as a means to offer new critical, playful perspectives on a new technology?

In a design education setting Ward and Wilkie (2008) create a curriculum for designers called 'mapping the user' and 'mapping controversy' where "students must become cognizant of and engaged in our technosocial, technoscientific world [...] from matters of concern that have not been settled and publics they may not have previously considered to the contestation of futures in the present." (ibid:3) In these courses students must take up the contested and difficult meanings of technologies as a resource for their design work, not to solve problems or increase efficiency, but to engage in technocultural issues through design. In this educational setting, designers engage in the cultures in which new interfaces, devices and designs can be made.

Many of these views of technology and culture share a common theoretical frame, commonly drawn from the Actor Network Theory (ANT) of Latour (2004) and Akrich (1992). In design research, Storni (2007) finds that the theoretical frameworks from ANT offer useful and diverse models with which to account for the processes through which designed artefacts are created. He finds that design processes involve

> practices of ordering, problem-solving, stabilization or closure where design objects are shaped and acquire a final material form, and where different concerns (aesthetic, technical, economical or material) encounter each other, become intertwined, and somehow hold together. (ibid:26)

Usefully, Storni uses ANT to account for the agency of materials and artefacts, the agency they acquire through a network of relations:

> both people and objects equally partake either in the construction, production and reproduction of the whole society or in the stabilization of facts and artifacts. (ibid:37)

John Law calls this a 'relational materialism' (Law 1992:383), where many of the things we think are human: thinking, learning, acting are all generated through networks that involve a network of heterogeneous relations between people and materials. Bijker and Law (1994) use the metaphor of a film script to describe the ways that

> technical objects define a framework of action together with the actors and the space in which they are supposed to act. (ibid:208)

How could design adopt digital humanities perspectives and attempt to see interaction design research as part of culture? Could we use a more trans-disciplinary analysis that contributes knowledge back to the field of interaction design research? Is it possible to find perspectives that allow us to see design as a creative, inventive and communicative field, that is fundamentally social, discursive and embedded in shared understandings of technology, material and culture?

Over the next sections I uncover some perspectives on the technoculture of RFID, it's dominant perspectives and concerns.

RFID: technical, cultural and historical perspectives

RFID is a complex socio-technical construction that already has widespread and significant, if mundane, impact on daily life. It is articulated through spectacular industrial visions and speculative proposals from research about its impact and implication for the future. Rosol (2010) undertakes a detailed historical investigation of RFID, from the initial patents in 1948 to its modern implementations. Although it's not explicitly noted in the text, his analysis takes a markedly material perspective as a strategy to bypass other confusing contemporary discourses:

> All the expectations of RFID's ability to form an augmented digital space are in fact bound simply to its capacity to transmit data via radio signals. Thus, instead of dealing with all of the digital futurism attached to RFID, I will undertake a historical excursion into a time when sociotechnical environments were almost exclusively set by analog radio communication. (ibid:39)

Rosol's approach to engaging in technoculture is through history and 'media archaeology' as a means of investigating the historically defined opportunities and constraints of media technologies. By tracing this material history of reflected radio waves he relates RFID to its historical, material development, in particular its relationship to the development of radar in 1948, he concludes that:

> Since RFID was forged in a time when the primary aim was to get ahead of the enemy in the continuing interaction between detecting and jamming, we ought to wonder how fragile and vulnerable an RFID-networked world and its alleged control over things, bodies and localities might eventually be. (ibid:49)

Through this technocultural and material perspective, the dominant rhetorics of control and security in RFID come into question. Rosol's analysis demonstrates that these cultural and material perspectives can be used to great effect in de-scripting an emerging technology like RFID.

A brief history of RFID

The development of RFID is based on radio frequency inventions that date back to the 1920s with the development of radar (Radio Detection And Ranging) systems. Radar, and the systems developed by the British to identify 'friend' from 'foe' (Goebel 2005) in the late 1930, can be seen as the ancestors of RFID technology. In the 1960s theories and

trials of RFID were developed, mainly in pursuit of 'article surveillance' systems for use in countering the theft of merchandise. The 1970s were a decade of intense research and development into RFID systems for collecting toll payments and animal tracking. Interestingly, although RFID standardisation was considered by the United States Federal Highway Administration, it was concluded that there was no interest in developing a standard for vehicle identification in the US, which lead to a proliferation of implementations of RFID systems, unhindered by regulation or standardisation (Landt 2005:9).

Figure 15: RFID systems in use in industrial logistics systems, where a reader is placed to identify objects passing by on a conveyor. Image from the author's visit to the Fraunhofer Institute for Material Flow and Logistics (IML) in Dortmund, Germany.

In the 1980s and 1990s commercial development of RFID systems and standards became mainstream, with the US leading the way in

automotive toll-payment, and Europe leading the short-range tracking of animals and products. The explosion of standards in the 1970s means that today a number of international, regional and industry-specific bodies, such as the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC) and EPCglobal, define RFID standards, most of which are incompatible. Unlike the 'Universal Product Code' barcode system, that was standardised early by IBM and the Uniform Grocery Product Code Council (Morton 1994), there is no internationally standardised way of implementing RFID to universally identify a product or an object. Industrial perspectives on RFID focus on its ability to identify and track objects from a distance (such as the conveyor gate in Figure 15, above) and its ability to be invisibly and seamlessly embedded into existing systems (Fleisch & Dierkes 2003).

The kind of RFID technology I am interested in here did not emerge until the late 1990s. These are two common types of RFID: low-frequency, 125 KHz RFID, and high-frequency, 13.56 MHz (Mifare) RFID systems that emerged as standards for RFID interaction. These systems are commonly used for Metro passes, hotel keys, library cards, credit cards and such, which are all applications where RFID and human activity are directly set in relation to each other, rather than distantly as in automated logistics systems. These kinds of RFID have become cheap and commonplace, and their interfaces have gradually slipped into everyday use. With almost four billion tags sold in 2012 alone, RFID systems are proliferating for many kinds of industrial and consumer applications. RFID is regularly used by millions of citizens of London, Paris, Oslo, Tokyo, Sao Paolo, Seoul, etc. to pay for public transport.

Figure 16: Using a variant of RFID, called Near Field Communication (NFC), in Nokia mobile phones to transfer contact data by bringing two handsets into close proximity, so called 'Touch to transmit'.

Promises and controversy

RFID is a technology that holds lots of promise and potential for interaction design practice and research. Designing systems and interfaces that take interaction out of desktops, mobiles and other screen-based interfaces, and brings them into the physical world, requires new means of designing and conceptualising services, user-flows and scenarios. Touching two phones together to transfer a contact through RFID (as in Figure 16, above) can be part of what Dourish describes as 'embodied interaction' where we are "interacting in the world, participating in it and acting through it, in the absorbed and unreflective manner of normal experience." (Dourish 2004). Yet these potentially small and unremarkable embodied interactions also entail

changes to databases, systems, financial transactions and perhaps even social relations. The act of buying a metro ticket, that used to be almost completely anonymous, is now accurately time-stamped, and linked to personal information and a history of use, which, for instance, has significant implications for law enforcement, as detailed by Hof (2007). So there are challenges of agency and control embedded in the design and use of these systems. There have been many attempts to engineer systems through which control, or perceived control, can be created in RFID systems, through 'privacy enhancing technologies'. One such study by Spiekermann (2007) showed that even after being shown RFID chips that can be turned on and off at will, people still reported feeling helpless and out of control.

RFID is a literally invisible technology, it uses radio waves to communicate and RFID tags are small enough to be embedded inside a wide variety of objects. This is seen as a great advantage over a similar identification technology such as visual barcodes, in that RFID does not need to visually change the surface of a product, nor does an RFID system need to be able to visually see a product in order to identify it. As Juels et al. (2005:2) notes "RFID in some sense endows computing systems with the ability to 'see' objects" while at the same time removing the human ability to see this identification taking place. This shifts agency away from humans and towards computing systems, This ability has been exploited as a means of increasing efficiency and control in complex systems like supply chain management.

However, although some aspects of RFID interaction have become stable and coherent, there are still aspects of RFID that are highly unstable and contentious. The discourse around RFID has become highly polarised, industry perspectives emphasise the possible economic impact of control over complex systems that RFID could potentially enable. The 'Gartner Hype Cycle', a central technology industry reference for tracking emerging technologies (O'Leary 2008) has shown RFID in some form every year for the last ten years. RFID is marketed as a technical innovation that will usher in a radically more efficient economy and everyday life (Bohn et al. 2004). Conceptually RFID is often expected to catalyse radical economic shifts, similar to those brought about by the internet. In this techno-optimist vision of an 'Internet of things' objects are smart, connected and trackable, around which new socio-economic systems might be invented. These visions of RFID are what Morozov calls 'solutionism', a term drawn from urban studies that recasts "all complex social situations either as neat problems with definite, computable solutions or as transparent and self-evident processes

that can be easily optimized" (Morozov 2013:5). We can see solutionism in the grand narratives of the EU's 'Disappearing computer' initiative (Streitz & Kameas 2007), and their 'Internet of Things' programme, that place RFID at the centre of radical changes in society and economics. But even within ubiquitous computing there are researchers who question whether these claims ring true. Lucky for instance wonders what happens when "Everything will be connected to everything else" but "no one has any idea what all those connections will mean." (1999:1).

Meanwhile, in reaction to these industrial speculations and visions, privacy groups protest against RFID and its potential for tracking of people and their possessions. RFID is often represented as an invasive, 'spy chip' technology that will allow for control by corporations and government. Central to these concerns is the invisible or seamless embedding of RFID tags in everyday objects. Invisibly embedding RFID in consumer goods such as razor blades, underwear and shoes is seen as an invasive practice that could extend to tracking the behaviour of consumers after purchase for marketing, analytics or other surreptitious uses. To reinforce these problems RFID has been associated with 'the mark of the beast' (Albrecht & McIntyre 2006) and with images of Big Brother, as well as Orwell's dystopian visions of the future.

The RFID privacy activists FoeBuD developed a material-semiotic artefact in the form of this RFID detector in Figure 17, below, that combines a functional 'privacy protecting' RFID detector into a symbolic object that also protests against the proliferation of RFID.

Figure 17: An "RFID detector" in the shape of a stop sign, designed and sold by FoeBuD. This simple circuit will make a light blink when in the presence of RFID radio signals, alerting the owner to potential privacy-invading electronic snooping.

Popular imaginations and folk-theories

Popular media representations of RFID include films such as *Casino Royale* (2006) and *Demolition Man* (1993) that depict human-implant RFID tags being tracked by satellites (Technovelgy 2009). In this scenario a chip is embedded under the skin, and a red dot will appear on a dynamic map, often allowing the antagonist (and the audience) to track our protagonist. This media trope is common enough that a satellite 'tracking chip' has its own page on the popular website TV Tropes (TVTropes 2012). In this sense we could look at RFID as a 'haunted' or 'monstrous' media that have had a long history of use as part of fiction and mythology (Sconce 2000). Lovecraft for instance depicted the telephone, phonogram and radio as haunted, 'monstrous' technologies that reveal hidden, grotesque truths.

Horrific and fantastic fictions often explore new technologies and media, as their "narratives revolve around attempts to witness impossible things and to prove their existence, tasks which involve not only the human senses but those technologies designed to extend and improve them: the media" (Kneale 2010).

Folk theories of RFID such as those found by (Poole et al. 2008) may be useful constructs for explaining how technologies work as practical, useful models. Previously, folk theories have been used by Friedman et al. (2002) to look at understandings of web security, and by Hendry (2006) looking at lay understandings of search engines. These 'lay' or 'folk' theories can have "profound impacts on how people orient toward ubiquitous computing technologies." (Poole et al. 2008:199). But when folk theory draws from popular media as in the examples above, they provoke fear and uncertainty about the devices we use everyday, and we "need to consider that popular culture can and does impact how people orient toward the systems we make." (ibid:199). By conflating the affordances of technology, and through association with conspiracy, government and the human body, technological monstrosity is constantly reinvented. RFID has been deeply affected by these popular media mythologies for the last ten years. This has been so serious, that an advocacy group for RFID, the AUTO-ID centre, commissioned a study of other technology failures (Cantwell 2002) in order to understand how to avoid a similar fate for RFID.

Towards a mundane reality

In this paradoxical process of a technology's 'emergence' there may be simultaneous exaggeration in popular media of both wildly optimistic and scarily pessimistic visions, but the technology often spreads out into the world in quiet and unremarkable ways. RFID is already in use by millions of people every day, in more or less mundane activities of opening doors and paying for transport: it speeds up a bus journey, simplifies the entry to a building, or replaces a physical key at a hotel. As Goffey and Fuller point out it is easier to be concerned with concrete, material, 'thick' media processes while overlooking the "dull opacity of devices and techniques not commonly viewed as media or forms of mediation" (Goffey and Fuller 2012:1).

The perspectives above, from industry, protest and media, largely assume that there are features inherent to the technology that make it 'efficient' or 'evil'. These conclusions about the technology are often drawn from an understanding of RFID that is speculative or propositional. I am consistently surprised that RFID clearly has material qualities (such as the

range of its radio waves and the size and material qualities of its antenna) that are rarely expressed as part of these perspectives. Without a more stable, foundational understanding of RFID as a material, it remains a frustratingly impermeable, opaque technology that may act as a vehicle for hyperbole or fear. It is relatively easy to make fantastic claims about a technology that is fluid and badly understood.

Although this gives us a picture of a contentious, emerging technology in flux, how do we approach the technology as designers? It seems that the mediation, meanings and mythology of RFID technology are some of the central things to address as part of any public design exercise using the technology. Can we be concerned with both the function of the technology as an instrumental interface, and its associated mediations and meanings as part of the cultures we design interfaces for? Is there a way of addressing and cutting through the binary, polarised essentialism in these views of RFID, in order to gain a better understanding of it? How do we address the material constraints and opportunities of the technology itself? And how might interaction design engage with RFID as a cultural phenomena, both in analytical ways and in the production of new perspectives that engage with popular imagination?

The disappearing interface

RFID is a doubly invisible technology: literally invisible as a technology, and invisible through normalisation into mundane, everyday interfaces. It is no accident that RFID is now a common interface technology and that it is disappearing into everyday life: invisibility is often framed as both an inevitable and desirable quality of technology. This can be seen in the discourses of ubiquitous or pervasive computing, in Human Computer Interaction (HCI), and in many parts of interaction design. For example Norman (1998) proposes the 'invisible computer' as the model for computing in the 21st century, while Ishii and Ullmer (1997:1) argue for 'seamless interfaces between atoms and bits', and Spool (2009) wants interfaces to 'be experienced and not seen'. These perspectives call for interfaces to literally disappear, using invisible sensors or interfaces embedded inside otherwise ordinary looking physical objects. They also call for interfaces to conceptually disappear, to become normalised into everyday actions and behaviours. From a digital humanities perspective on Virtual Reality, Bolter and Grusin (2000) point to a "medium whose purpose is to disappear. (21)" where there is an intention to "diminish

and ultimately to deny the mediating presence of the computer and its interface" (23).

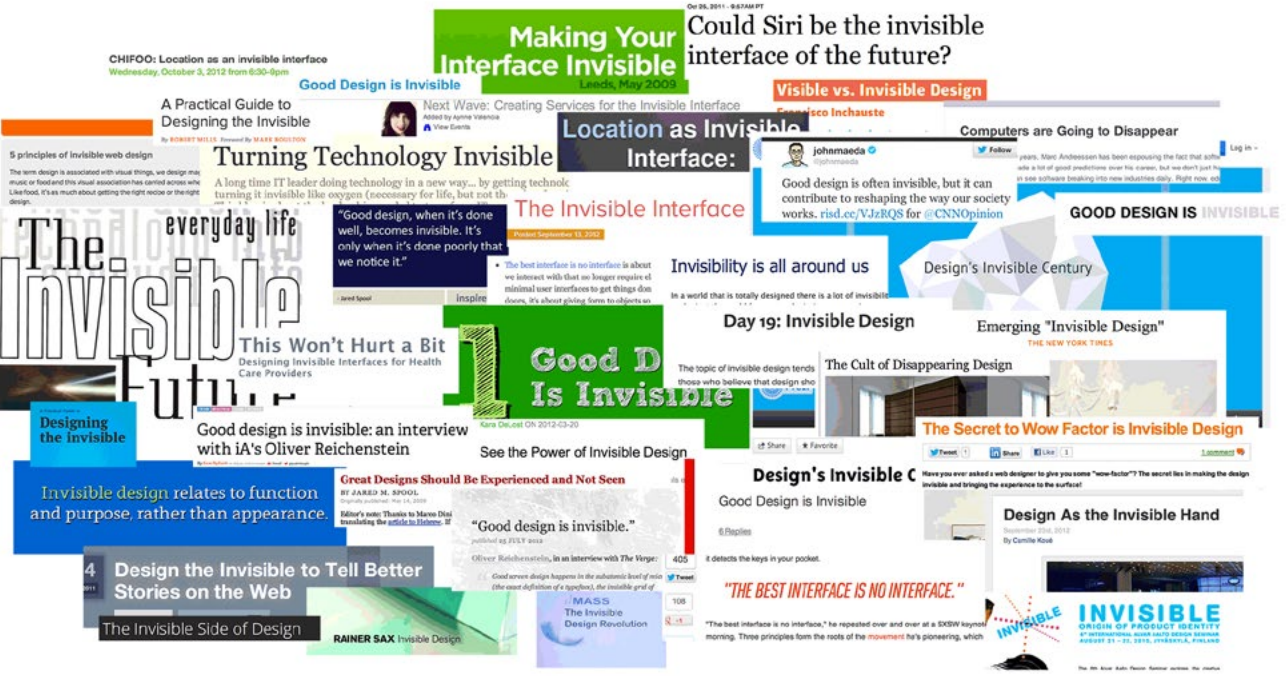

Figure 18: A collection of articles, essays and presentations about 'invisible design' collected between 2009-2013.

There is an entire movement called 'invisible design' within interaction design, under such headlines as 'good design is invisible' (Reichenstein 2012) and 'the best interface is no interface' (Krishna 2013). Some of the headlines from these articles, books and essays can be seen in Figure 18. Meanwhile Apple has popularised invisibility as a central technocultural theme by opening their commercial for the iPad 3 with the line 'We believe that technology is at its very best when it's invisible' (Apple 2012).

This mirrors historical debates about the visibility of other technologies. For instance in typography it was argued by Warde (1955) that the ideal aim of a print should be that it is invisible to the reader, that typography was best when it disappeared. We now accept that typography can be both invisible as part of a well-set paragraph in a novel, and it can be both functional and highly visible, even experimental, when it is part of signage or in public lettering (Baines & Dixon 2003).

The stated aim of making many contemporary interfaces invisible is to create more so-called 'natural' or 'intuitive' interactive experiences. For instance Rekimoto (1997) talks about the use of physical objects as 'natural' ways to manipulate digital objects (33), Anokwa et al. (2007:1) talks about RFID in mobile phones as a more "natural interaction between users, devices and their environments." In these texts it is argued that an RFID interface will somehow be more natural than one based on a screen. An RFID-based ticket turnstile might allow for more 'embodied' interaction, we can avoid using a screen or other visual information such as a ticket and can instead use movement, our body, and gestures to interact with the transport payment system. But does this mean that an RFID system is inherently more natural than a screen-based one?

As has been argued convincingly by Raskin (1994:17) the concept of 'natural' or 'intuitive' is almost always necessarily about familiarity. Desktop and WIMP interfaces were 'intuitive' relative to earlier symbolic and text-based interfaces because they relied on concepts, abstractions and metaphors drawn from the visual, physical world that were familiar to a large number of people. If the aim of contemporary interaction design is to make invisible interfaces how do we explain and instruct for their use? How can we build knowledge about sensor technologies, such as cameras and RFID, that have very distinct and not necessarily simple or familiar qualities, as described by Reeves et al. (2006)?

The normalisation of RFID is an additional form of invisibility that may be problematic for technologies as they become ubiquitous and articulate more central roles in daily lives and greater potential for misuse. As RFID becomes an everyday technology it recedes into the 'background' infrastructure of everyday life and this backgrounding limits our ability to see alternative uses for it. The fact that technologies like RFID are invisible make them doubly difficult to change or criticise (Hjelm 2005). They become so ingrained that we are unable to break out of the conceptual models that are embedded in these systems. This leads to a lack of agency or critique over the technology, but also in smaller ways reduces our ability to see alternative uses for it, for instance what about playful and social interaction potential outside of the utility of the transactional?

Figure 19: 'Honda Click' Commercial. http://www.youtube.com/watch?v=_MjG6UYopBo

Figure 19 is a television commercial that brilliantly illustrates the technologies that are already normalised in everyday life. After 20 seconds of macro-close-ups, often surprising perspectives on daily interactions between people and various objects and interfaces, the voice-over asks "why is it the better something does its job, the more we take it for granted?" This poetically associates the design of Honda cars with everyday, satisfying and reassuringly physical interactions through its careful editing and sound design. It is remarkable how many interactions we can identify with, it sensitises the audience to otherwise 'invisible' or normalised interaction.

If we are to design with ubiquitous technology like RFID, and to be able to understand and critique it then we need to find methods to counter this normalisation of technology in everyday life. As Goffey and Fuller would put it, we must engage in the 'grayness', the 'gray media', the "devices, practices, protocols and procedures, gadgets and applications [...] the vast

black-boxed or obscurely grayed-out zones, taken for granted, more or less stabilizing or stabilized artefacts." (Goffey and Fuller 2012:4).

The concept of seamlessness

The term seamlessness has had a central role in the history of ubiquitous computing led by Weiser (1991) who published "The Computer for the 21st Century". Seamlessness is the "deliberate "making invisible" of the variety of technical systems, artifacts, individuals and organizations that make up an information infrastructure" (Ratto 2007:21). Seamlessness presumes that invisibility a desirable quality of interfaces and information systems. Seamlessness is an attractive and persuasive concept, embodying the idea of reducing the amount of time we spend dealing with interfaces rather than tasks. It also describes some of the desirable use-cases in complex infrastructural 'ecosystems' such as Apple's iTunes where music and media are synced across devices, calendars stay up-to-date and your notes somehow pop up on the desktop after writing them on a mobile device.

Perhaps one of the best illustrations of a vision of seamless technology is the Honda commercial for its 'Integrated Motor Assist' technology that allows for the engine of a Honda car to turn off when its not needed. Called 'Sense' the commercial depicts a world in which all of our daily technologies, from TV screens to fluorescent lights are aware of human activity, and they respond by turning off when they are not needed.

Figure 20: Honda 'Sense' Commercial. http://www.youtube.com/watch?v=cvEdFIonspk

The speculative vision of technology in Figure 20 was produced as a means of persuading an audience about a spectacular future of Honda technology. Although not the work of computing researchers or directly about ubiquitous computing, it reflects on the contemporary themes of human-computer interaction and the ubiquity of sensing technologies. As an evocative and speculative commercial it situates itself just outside the realm of possibility, poetically making the case for a technology that 'knows' when it is not needed. The world it represents however is eerie, spooky, ghostly, in which lights mysteriously blink on and off and haunted cookers turn down the gas. It raises the question of whether seamless, invisible interfaces are desirable, or even acceptable or marketable when their media representations are so akin to horror.

Analytically seamlessness has been problematised from many angles. Even as far back as 1991—the same year that Weiser published his manifesto—Haraway wrote *A Cyborg Manifesto* where she wrote:

> "Our best machines are made of sunshine; they are all light and clean because they are nothing but signals, electromagnetic waves, a section of a spectrum, and these machines are eminently portable, mobile. [...] The ubiquity and invisibility of cyborgs is precisely why these sunshine-belt machines are so deadly. They are as hard to see politically as materially." (Haraway 1991:153)

More recently Ratto (2007) calls for us to "critique the clean, orderly, and homogenous future that is at the heart of these modernist visions of ubiquity and use these critiques to better understand the ethical dimensions of our increasingly socio-technical world. (ibid:26)". In what might be a starting point for a design methodology to discover the 'object-worlds' of technology, he finds that the "seams between systems provide the most opportunity for extending, troubling, and repurposing infrastructures. (ibid:25)." Ratto finds that seamlessness

> articulates a particular kind of passivity and lack of engagement between people and their actions and between people and their social and material environment. (ibid:20)

By hiding and smoothing over the technical edges and seams, we may impair our understanding and critique. There is also a sense in which culturally there is no longer such a need to 'hide' the technology from view, or to create such seamless technological experiences. Huhtamo argues for challenging the 'exaggerated idealist rhetorics' around the dematerialising effects of VR, and that in fact "Technology is gradually becoming a second nature, a territory both external and internalized, and an object of desire. There is no need to make it transparent any longer, simply because it is not felt to be in contradiction to the 'authenticity' of the experience." (Huhtamo 1995:171).

These questions are rarely addressed apart from a notable few. From an HCI perspective Reeves et al. (2006) suggest that designers of invisible, sensor-based systems should "consider the complexities of the spatial character generated by sensor devices" and that we must evaluate the "relative merits of hiding and revealing these to users." (ibid:40).

At the heart of disciplines that design digital, computational systems for use is the concept and process of abstraction (e.g. Aho & Ullman 1992, Kramer 2007, Conley 2004). We necessarily create useful abstractions of complex systems and technologies, and the full picture of the computational machinations going on underneath should be invisible to our users or audiences. But I find it problematic to aim for the invisibility

of interfaces as the outcome of interaction design, as this seems to both work against the aims of usable, familiar interfaces and creates the conditions for the problems that Hjelm identifies: a reduction in agency over technologies and a reduced capacity to critique interfaces.

As we have seen invisibility is an innate, literal quality of many contemporary interface technologies like RFID. However seamlessness is a designed, conceptual quality of interfaces, it is a construct of the technological imagination. It is not a quality of digital interfaces or sensing systems, which must always be engineered and designed towards the deliberate hiding of technical edges, seams and infrastructures.

In summary, RFID is fascinating because it represents many of the contested meanings around emerging technology, including the problems and opportunities of seamlessness and invisibility. In the next section I lay out the concepts of mediation and remediation that can be used in the analysis of these RFID interfaces.

Mediation and remediation of interface technology

In the concept of mediation, introduced by Vygotsky (1978) in the context of psychological development, learning is conducted through cultural and interpersonal communications that are mediated by different cultural tools and signs. According to Kuutti "When we plan to act in the world, our action is shaped and conditioned by the available means, mediating tools, which are the result of a cultural historical development." (2009:4) These 'mediational means' were conceptualised by Vygotsky as either physical tools used for shaping the material world, or symbolic psychological tools used in the development and change in individual or shared thinking. Kuutti sees mediation as a central means of understanding design, where the work of a designer is to "purposefully create a new set of relationships, or to change an existing one—in one word, re-mediate." (ibid:5). Kuutti develops the concept of triple-mediation, where she draws on both Bolter and Grusin's (2000) work on remediation and cites Krippendorf's early work on product semantics where he suggests that an artefact carries at least three mediated relationships at the same time:

> Artifacts are not only instrumental to users (operational context) and constitutive of social realities (sociolinguistic context), but

> they are also created, produced, marketed, consumed, retired, or recycled, and experiences with them inform a subsequent generation of artifacts. (Krippendorf 1989:13).

For Kuutti these three kinds of mediation: instrumental, symbolic and remediated, offer a venue and an approach to artifact-mediated relationships between humans and world. In a similar direction, Eikenes (2010) develops the concept of double-mediation, where visual interfaces are seen as both tools and signs in their mediation of human activity. As instrumental mediation, interfaces enable activities to take place, much like a tool or an instrument. However, in order for this to happen, interfaces must be made meaningful through the use of signs, through semiotic mediation. Interfaces in HCI are generally seen as tools, where they can be optimised for work and usability, but designers may also draw on approaches from digital humanities where an interface may "be described as a cultural artefact that functions as a medium for communication, directly as well as indirectly." (ibid:63). In Eikenes' formulation, semiotic mediation is drawn from the conceptual frameworks of social semiotics, while instrumental mediation is drawn from activity theory. This mix of conceptual foundations builds an ability to account for the richness of interfaces, from the aspects that allow for activities and functionality, to their meanings, representation and interpretations.

Theorists Jay David Bolter and Richard Grusin call attention to the way in which new media splice together different kinds of existing media that entails a remix of older media forms by newer ones. As they put it:

> all mediation is remediation. We are not claiming this as an a priori truth, but rather arguing that at this extended historical moment, all current media function as remediators and that remediation offers us a means of interpreting the work of earlier media as well. Our culture conceives of each medium or constellation of media as it responds to, redeploys, competes with, and reforms other media. In the first instance, we may think of something like a historical progression, of newer media remediating older ones and in particular of digital media remediating their predecessors. But ours is a genealogy of affiliations, not a linear history, and in this genealogy, older media can also remediate newer ones." (Bolter & Grusin 2000:55)

Figure 21: A billboard advertising Apple's iPad Mini, mid 2013. The three uses of the tablet are represented through remediated images of previous interfaces and media types.

In interaction design research, the notion of remediation is central to foundational concepts such as the way in which complex, 'hypermediational' interfaces work. Bolter and Grusin find that the "graphical interface referred not only to culturally familiar objects, but specifically to prior media, such as painting, typewriting, and handwriting. In making such references, computer designers were in fact creating a more complex system in which iconic and arbitrary forms of representation interact." (Bolter & Grusin 2000). Such remediation at work can be seen in the advertising for Apple's iPad Mini in Figure 21. Earlier Simon Penny has pointed out that 'Paintbox' software "is only intuitive because the paintbox is a culturally familiar object" (Penny 1995:55). This is not just an analytical concept, but a productive technique that designers take up in their practice, as Eikenes points out "we draw

on earlier texts and artefacts not only in the interpretation of texts and artefacts, but also in their design production." (Eikenes 2010:86).

Murray finds that due to its relative newness, and a diverse theoretical and practical history, that "digital design has been hampered by the lack of useful common vocabulary" (Murray 2011:8). In contrast, architecture, furniture and fashion are rich areas for inventive, experimental, explorative design because, as Murray puts it they have "a well-stocked cultural inventory" (ibid:3) from the many millennia that humans have been sheltering and clothing ourselves. In fact Don Norman's influential book 'The design of everyday things' is in part a catalogue of existing cultural norms, presented as a method for incorporating these 'affordances' into new designs (Norman 1988).

However, as interaction design moves from the 'hypermediational' representational space of the computer desktop and out into the world through mobile phones and other ubiquitous interfaces such as RFID, we are in an ever-expanding need to be able to understand, analyse, remediate and reformulate existing cultural forms. The history of ticketing, of both urban signage and computer iconography, as well as an account of our understandings of radio and popular mythology of physics and 'action at a distance', these are all considerations that need to be accounted for in design research and practice.

We should be able to internalise and apply a knowledge of the cultural understandings of technologies and interactions in order to both design 'intuitive' or familiar, 'user-centred' products with the technologies at hand. But we also need to be able to use these concepts to understand the 'object-worlds' of the technologies themselves, not as neutral, abstract or novelty, but as a set of opportunities with rich set of cultural meanings, both pre-existing and possible.

We need to look at remediation of RFID technologies in order to address the technocultural imagination. Through this kind of analysis we can see that it has paradigms that are culturally dominant, and that need to be challenged: the rhetoric of seamlessness, of invisibility, of frictionlessness and of the 'internet of things' are all dominant themes that are used to simultaneously exaggerate the possibilities and downplay the limitations of the interactional medium of RFID. In comparison to the modernist movement in art, Clement Greenberg's influential account found that rather than using art to conceal the medium, Modernism used art to call attention to itself: "The limitations that constitute the medium of painting — the flat surface, the shape of

the support, the properties of the pigment — were treated by the Old Masters as negative factors that could be acknowledged only implicitly or indirectly. Under Modernism these same limitations came to be regarded as positive factors, and were acknowledged openly." (Greenberg 1960). A design approach which reveals the phenomena, the seams and the infrastructural qualities of RFID technology, could be used to challenge the received understandings of RFID as seamless and transparent.

The cultural remediation of RFID already takes place in at least two ways. Firstly RFID technology remediates everyday interactions with the infrastructure of the city, by subtly changing the way in which people interact with transport, services and civic life. A tram user may still understand an RFID pass as a ticket, but has a set of new gestures to learn, and new kinds of connection to the transactions, objects and services. Secondly RFID also remediates our shared imagination of the ontology of technology, from static, screen-based, situated, time-delimited, desktop computing, to ubiquitous, screen-less, always-on, service-based, pocketable and disposable. Our imagination of the nature of technology is changed through our experiences and our use of RFID, and through the way in which it is marketed, represented and mythologised.

Defining digital design materials

Materials and materiality have become an increasingly important concern as interaction design has matured as a design discipline over the last two decades. Traditionally design has had a highly material foundation developed from craft traditions. Schön describes designing as a 'reflective conversation with the materials of a design situation' (Schön 1992:3) in which designers interact with their intermediate design representations.

The form and function of a physical product cannot be designed without some knowledge of materials. In industrial and product design, materials are tested for their properties, their bendiness, strength, resistance to heat, scratching etc. using a number of standard tests. Industrial designers are familiar with instruments for materials testing, that can measure the 'properties of materials and components using tension, compression, flexure, fatigue, impact, torsion and hardness tests' (Instron 2012). This kind of material exploration involves the materials being unpacked, pulled apart, broken, reconstructed and re-shaped in order to test their strengths and weaknesses. The traditions of industrial

design emphasise a high degree of material knowledge in the processes of invention (eg. Manzini & Cau 1989).

In interaction design the investigation of materials has largely focused on software. Theories of digital design materials have been developed to deal with the intangible, immaterial nature and behaviour of code (eg. Jung & Stolterman 2011, Vallgårda & Redström 2007). Hallnäs & Redström's (2006) notion of computing as a material for design is an important development that has allowed them to consider the aesthetic aspects of interaction in their work. Against instrumental and functionalist views of interaction design, they remind us of the 'expressiveness' of computational materials, and "the ways in which computational material can build things and systems. The notion of design material is in this sense central for the methodology of interaction design aesthetics." (ibid:216).

Fernaeus & Sundström (2012) suggest that there are three reasons that both interaction design and HCI have underestimated the importance of material knowledge in the design of interactive systems. First, they find that it is "the complexity of the digital in how it unfolds over time and space, which makes it hard to show, share and fully understand" (ibid:488). Second, there has been a conviction, particularly in relation to software, that 'the digital' "is a plastic material in which we can build almost anything". This reflects Hallnås' view that in interaction design "the material we 'use' is in many ways abstract and we tend to think of it not as material, but as expression neutral technology." (2006:418). One such view, of digital 'material without qualities' (Löwgren & Stolterman 2004) disregards the fact that hardware and sensing systems have many physical and material qualities. Third, they propose that "many of the 'materials' worked with in this field are themselves changing over time, making designers uncertain of their value in terms of lasting knowledge." Further, I would argue that design's recent focus on user-centred and participatory practices has led to a relative neglect perspectives that take up the materiality of interaction design. This argument is elaborated further in Article 1 (Arnall 2013 in press).

Dourish and Mazmanian (2012) offer a typology of five interwoven approaches to materiality with the intention to "illuminate the consequences of the particular and various materialities of information as they arise in organizational, social, and cultural practice." (ibid:3) They are interested in material properties and how "Information practice arises in conversation with these specific properties of information and its material forms." (ibid:4). Their typology includes: the *material culture*

of digital goods, the *transformative materiality of digital networks*, the *material conditions of information technology production*, the *consequential materiality of information metaphors*, and the *materiality of information representation*. In particular they focus on the representational consequences of digital materiality, how the particular forms that information takes—graphical, lexical, databases—shape the kinds of manipulations and analyses it supports. Their analytical approach is supported by two examples: the physical materiality of digital photography and the contested materiality of nuclear weapons simulations. This study is an attempt to bring material culture into HCI, and while interesting, is of little relevance to perspectives on the materials of interaction design research.

Outside of these typological and ontological arguments we discover that there is a relative lack of means for understanding and discussing materials in interaction design. Perspectives on the generative nature of digital materials, as resources and foundations upon which design work is done, is missing. There is a significant and unexplored area around the materials of interaction design where we might see materials and material repertoires as "a tool for inspiration as well as production" (Nordby 2011:91). These issues are currently limited to interaction design practice, through ad-hoc experimentation, through assumptions or through the highly technical discourse of engineering. In all of these accounts of digital materiality, we don't find an approach to design materials that includes the way in which designers might be able to generate their own material perspectives, particularly around the development of tangible and ubiquitous interfaces:

> with the recent development of accessible and sensor-rich mobile platforms, it is no longer unusual that researchers in more conventional design projects make use of more elaborate sensor solutions as parts of their designs." (Fernaeus & Sundström 2012)

What approaches should designers use to gain a greater agency over and understanding of the material of interaction design technology? How do we unpack the assumptions embedded in a modular component for instance, or formulate an approach to optimising battery life, or approach the relative merits of different emerging wireless standards? In a very Latourian sense, Balsamo sums up this perspective on technological material:

> Agency—defined pragmatically as the ability to affect the technological outcome—is not an exclusive privilege of human

> beings. In the process of designing, the matter of the world also manifests agency". (Balsamo 2011:33)

What concepts can be used to account for the agency of interaction design materials, and how could these be used to gain agency over technical materials?

Material exploration

According to Schön (1984) designers develop an understanding and framing of their problems through experimentation or what he calls 'design moves' that ask 'what if I did this?'. Design moves "function in an exploratory way, the designer allows the situation to 'talk back' to him, causing him to see things in a new way." Schön (1984:132). The concept of a 'conversation' with materials is rather abstract, even though it is often cited as a central aspect of design research. What are the actual concepts and practices that are taken up in the exploration and understanding of design materials? What follows is an outline of the concept of *material exploration*, an experimental design practice for exploring emerging technologies.

Exploring technology has been seen as problematic in both user-centred disciplines like HCI and in the humanities. A lack of attention to technological materials can be attributed to a number of factors. The reasons for the lack of material focus include four suggested by Fernaeus & Sundström (2012). The strongest here is perhaps that interaction design and its close relative HCI have been framed very much as user-centred disciplines, with a focus on user-centred, user-experience and usability methodologies. The the term 'technological determinism' has been used to critique technology-led explorations and experiments in many disciplines including interaction design, in favour of user- or human-centred perspectives. They also suggest that interaction design materials are complex in the way they unfold over space and time, which makes them hard to see and share. They are also seen as plastic, 'materials without qualities' with which we can build almost anything, that thus do not require formal attention. They are also in constant change, as technologies develop, and thus difficult to pin down and uncertain in value of long-lasting knowledge.

In addition the materiality of technology is intentionally hidden and abstracted through processes of systems design and engineering. These processes modularise away the complexity of technology, and in doing so hide the underlying materiality of computation, networks, radio and such. But why should design be a method to look at technology? First of

all there is no discipline that doesn't in some way use or have taken up issues of technology, and in this sense technology is a postdisciplinary object. As Balsamo puts it, technology "no longer properly belongs to the special few (the philosophers, the engineers). Instead this suggests that thinkers in several disciplines might have something important to contribute to our collective understanding of the "nature" of technology." (Balsamo 1999:88). She quotes Zoë Sofoulis and says that

> we cannot hope to properly reflect upon and understand the character of modern technology by merely staring at the technological. Instead we must inquire into what our technologies tell us about our ways of seeing and revealing the world. [...] We must reflect upon what modes of revealing they present, what questions they pose about dominant forms of technological revelation, what glimpses of alternative configurations they offer. (Sofoulis 1993:11)

In an anthropological study of engineering design practices Bucciarelli gives multiple accounts of highly technical practices of designing electronic components and products. He describes designers as having highly personal, "objective, instrumental, often formal and abstract" models and explanations of the materials, components and phenomena that they are working with. He describes these as 'object-worlds';

> theories, explanations, knowledge of tolerances, specifications, images, stories, alongside "personal renderings of scientific principles and technical possibilities." (Bucciarelli 1994:76)

These different object-worlds are not consistent: "there is no overriding perspective, method, science, or technique that can control or manage the design process in object-world terms" (ibid:159). So from these different perspectives designers must construct, communicate and resolve scenarios about how materials and objects are going to behave in action. Bucciarelli describes negotiations about 'object worlds' as happening as part of design practice, in the production facilities and laboratories, preferably directly, face-to-face.

If we look for material approaches from the more technical disciplines involved in technological innovation such as Ubicomp, HCI and engineering we find that there is little foundational work. This work often takes up an approach that is about the optimisation of systems, infrastructures and the direct relationships between users and artefacts. These studies often have hypotheses about intended interactions, and

as Vallgarda (2009) points out, these kinds of studies commonly situate *use* as the 'operationalization' of the artifacts, where "users are employed as the reality whose actions, in the situation of use, constitute the resistance that we measure the artifact against," (Vallgårda 2009). The evaluation of this research is then in how well the initial assumptions and hypotheses about the interactions of an artefact matched up to its use. Even in more experimental aspects of HCI research such as probing (e.g. Gaver et al. 2004, Paulos & Jenkins 2005, Hemmings et al. 2002) the operationalization of artefacts is to study the contexts of interactions and use. Mazé talks about critical practice in design, using interaction design practice to design products that "open up for 'active critical participation' outside and after design." but here the artefacts set up the "conditions for participation" (Mazé 2007:16). These are methods for generating user-centred technical innovation in measurable steps, relying on scientific criteria such as reproducibility, reliability and validity.

What does interaction design look like outside of these user-centred models? How should we frame a practice that takes up technological phenomena as design materials? As Vallgårda asks, "what do operationalizations look like when focus is on these other aspects of design, when materials or forms are the subject matter?" (Vallgårda 2009:184).

Experimental design is a means of exploring a subject area through a practice of making, without direct formal or commercial constraints. It is not a free-form practice such as art, it is still guided by design methodologies and materials, collaborative, studio or workshop based, and it uses design briefs as loose 'hypotheses' about the subject area. From a scientific point of view Brown calls experimentation "not merely a procedure for producing neutral evidence, but rather a way of *making* and *doing* that puts the hypothesis into practice" (Brown 2008). It is this emphasis on making and doing that defines experimentation even in the rigorous practices of science. According to Vallgarda, experimental design research consists of a program that "sets the principles for a design space, and the experiments serve to explore various facets and edges of the program" and she finds that these kinds of design programs typically operate on the future context, and do so through "a question, an operationalization of the subject matter, and an evaluation of the result" (Vallgårda 2009).

In this thesis I specifically take up the issue of exploring the technical material of RFID. There are many reasons for this, but it is summarised by

Murray (2012) who recognises that the technical material of an interface technology has a deep impact on the meaning of that technology:

> When the technical layer changes, the possibilities for meaning making change as well." (ibid:12)

In their conclusion to a paper on the importance of materials in interaction design, Fernaeus and Sundström (2012) call for four activities that researchers should be engaged with that I summarise below:

- *Material explorations*: What are the limits, possibilities, and properties of specific materials?
- *Methods for material explorations*: How do we achieve understanding and knowledge of a new material?
- *Methods for communicating material properties, and possibilities*: How can the material properties be communicated to, and understood by various stakeholders?
- *Practical application of knowledge gained from material explorations*: How may deep understandings of material properties be used concretely as a resource in interaction design?

I find these activities pertinent to contemporary interaction design and this thesis gives an account of such approaches to RFID over the next two chapters. In addition I think there are additional issues to answer and activities required. How for instance does design materialise and establish something that is not yet seen as a material? This seems to be an ongoing issue as new technologies emerge and the technical foundations of interaction design change.

There is also the issue of communication across disciplinary boundaries and towards the popular imagination. Taking up the materiality of technology for the public and for other disciplines interested in technological development and critique seems like something that design research would have a potential role in doing. And what about the negotiation of these materials and 'object-worlds' beyond the face-to face? Every designed object, be it an electronic component or a new plastic material or a web service comes with an embedded, and often hidden, world that is the sum of someone else's activity or design work. How do we share and negotiate the world of objects beyond the boundaries of the design studio or workshop? Are there ways of opening up these

object worlds to wider discussion and critique as part of the popular imagination?

Visual communication

The title of this thesis, 'Making Visible', is intended to describe two central focuses of the research: the making of materials and the visible mediations of interaction design. I have covered the concepts of material exploration in interaction design above, but what about visual mediation? In this next section I explore some of the concepts of visual communication and their role in my design research.

Design practices play a significant role in the ways in which new technologies are communicated, whether through the industrial design of a new device, the interaction design of a novel interface, the information design of instructions, and even in the graphic design and advertising of new interactive products. Communication is seen both as a critical factor in these design processes (in the studio or workshop, amongst designers and collaborators) and in the designed objects (in the meaningful shapes, forms, symbols that communicate to users). I detail these below, but first I outline some of the semiotic foundations underneath these perspectives.

Semiotics in design

Theories of communication in graphic design typically fall into two perspectives. The first, a modernist, process-oriented, perspective is concerned with the actual processes of communication, where concepts such as 'transmitter', 'receiver', 'encoding' and 'decoding' reveal a focus on efficiency and accuracy of communication. Similarly, the term 'communication' in interaction design and HCI is often used to represent technical processes: the protocols or systems behind a 'communications technologies' for instance. This concern with the technical processes of communication emphasises the media or channels through which messages are 'transmitted', and is also evident in models of communication between designers and users, as illustrated by Crilly (2008:17). These models are drawn from Shannon & Weaver's (1949) model of information transmission that focus on *intended meaning* and the way that meaning is transmitted. This model has inspired a wide range of models of communication in design—see for example Moody (2009) and Crilly et al. (2008)—even though the adaptation of the metaphor to human models of communication was not Shannon's intention (Maier et al. 2005:246).

In these models, if the receiver gets a different message than the transmitter intended, it reveals a flaw or a breakdown in the communication process. The intention of the sender are crucial in defining a message, while issues of culture and interpretation are downplayed. In some modernist perspectives, visual symbols are seen as a universal, boundary-less means of communication. Otto Neurath (2010) for instance saw his ISOTYPE (International System of Typographic Picture Education) system as a means of "enabling everyone to take part in argument by means of a common visual basis for information." (ibid:126). Although this aim is laudable, and Neurath's work is expressive and inspirational, the focus on universality of intent and encoding into symbolic form does not account for the complexity of visual and communication cultures.

Instead, I focus throughout this thesis, on a second approach to communication drawn from semiotic perspectives. This perspective is concerned with communication as the generation of meaning through the construction of signs, symbols and messages. As originally defined by Saussure, semiotics is "the science of the life of signs in society". Rather than focusing on the process of communication, this perspective regards communication as a part of the construction and exchange of meaning. Different and oppositional interpretation within communication is a reflection on the plurality of messages, and the different cultural and contextual perceptions of readers, not a result of a failure of communication channels. Semiotic perspectives focus on the text (in the broadest sense which can include speech, writing and images as different 'modes') and the readings of that text.

Semiotics is a move away from theories where form and meaning are dealt with separately, towards a concern with form-and-meaning: "a fusion of form/signifier and meaning/signified" (Kress 2004:41). Multi-modality in social semiotics has a concern with the form and meaning across many modes: of text, speech, images, sound, each of which are governed by "distinct logics, and have distinctly different affordances." (Kress 2004:1). In social semiotics and multi-modal analysis an interface may be seen as multimodal text—a meaningful artefact that communicates through modes such as sound and images (Kress & van Leeuwen 2001). In multimodal analysis 'texts' are seen as part of their wider socio-cultural contexts, alongside and against other 'texts'. In the transition to digital communication, the use of multiple modes such as text and image has become usual and unremarkable. Designers can choose the mode best suited for a message and for a particular kind of reader without significant additional 'cost'. Although text is governed by

the logics of time and linearity and images are governed by the logics of space and simultaneity, multimodal analysis suggests that both can be 'read' and analysed through grammar.

In interaction design, how are interfaces treated as 'texts'? According to Eikenes "the interface may be seen as a symbolic and cultural artefact as well as a physical tool that mediates human action." (Eikenes 2010:15) In this view, the interface as a tool is wrapped in a sign:

> This is to indicate that in order to access a tool or an interface there is first a process of interpretation to understand its potential use and meaning. This process of interpretation continues throughout use, as a person interprets the results of his or her actions. (ibid:67)

This important distinction allows us to treat interfaces as objects of mediation and signs that have processes of interpretation.

Visualisation

The concept of visualisation exists across disciplines, but particularly in the sciences. Although visualisation has traditionally been seen as part of science, statistics, demographics and cartography, it has in the last few years become part of the visual culture of many disciplines. Visualisation practices have flourished particularly in interactive media and online journalism, as noted by Smith:

> While information visualization certainly can be read in relation to statistical or cartographic traditions, it is crucial to recognize the intrinsic connection between this medium, and interface culture" (Smith 2009:205)

Visualisation has become an educational and communicative tool that has emerged as a means of exploring and explaining an increasingly complex and data-rich society and culture. Information visualisation is increasingly social and accessibility-oriented, no longer designed 'by experts, for experts' but designed to be relevant in mainstream culture, and to be shared by broad audiences online (Danzinger 2008). This move has brought with it the problem of visualisation literacy and the risks inherent in the persuasiveness of visual explanation. In their classification of the risks of visualisation Bresciani and Eppler (2009) find that "visualization may be ambiguous due to its intrinsic conciseness and abstraction, as it conveys condensed concepts or information in a much more encoded way than an equivalent text." (2009:14).

Related to visualisation, the concept of the epistemic artefact, a knowledge-carrying object, has emerged. (Tweney 2002) gives an account of Faraday's search for the optical effects of gold, through his constructive making of about 600 microscopic slides. By studying these slides, rather than a linguistic account of Faraday's discovery process, Tweney aims to uncover the 'manipulative abduction' that characterises this kind of exploration, to:

> fully capture the way in which Faraday interacts with the materials and objects of his laboratory to shape his model construction activity." (ibid:2)

Faraday's slides are part of a long history of imaging and visualisation in science, mathematics and engineering. The purpose of imaging and visualisation has been to bring the imperceptible into the range of human perceptions, to adapt the world to our human senses. Microscopes image small things at human scale, telescopes do the reverse, while advanced imaging techniques such as X-rays and Magnetic Resonance Imaging (MRI) make opaque physical matter transparent to the human eye. As Tufte (1983) has pointed out, visualisation has been a key aspect of mathematics and statistics, making clear patterns from otherwise abstract sets of numbers or large data-sets.

The visibility of interfaces

Early HCI work concentrated on defining the visual abstraction and metaphors for computational behaviour in graphical user interfaces. The analysis of the communicative qualities of graphical user interfaces are fairly well understood, for instance see early work on Graphical User Interfaces (GUIs) by Mullet & Sano (1994). More recently, You & Chen (2007) proposed a model for the relationships between visual symbolic information and perceptual information and affordance. They argue for the importance of combining visual symbolic information with other kinds of affordance and perceptual cues in order to design interactive products. In his concise history of interaction, Dourish (2004) finds that the most significant development in user-interface models was the transition from textual to graphical interaction. By moving to two-dimensional representation, input and output could occur in multiple places, and attention could be spread across a large screen area. It was graphical interaction made it possible to exploit further areas of human ability in interaction, such as weighting of information density to take advantage of peripheral attention, or laying out information in ways that allowed for pattern recognition and spatial reasoning (2004:12). Graphical interfaces also opened up for visual metaphors for information

management, the use of filing cabinets and trashcans to represent actions and context, which also opened up for the concept of 'direct manipulation' of these representations (2004:13).

Norman (1998) calls visibility "one of the most important principles of design" (ibid:4), and that the principle of visibility is "violated over and over again in everyday things (ibid:100). In his view, visibility is the way in which objects indicate the mappings between intended actions and actual operations, the way in which objects distinguish between themselves, and the ways in which the effects of operations are displayed.

> It is the lack of visibility that makes so many computer-controlled devices so difficult to operate. And it is an excess of visibility that makes the gadget-ridden, feature-laden modern audio set or video cassette recorder (VCR) so intimidating. (ibid:8)

Here Norman calls not just for more visibility, but appropriate visibility, to make the "relevant parts visible" (ibid:99). He calls on designers to improve feedback and to give users the ability to keep control over their everyday things.

However, a more recent focus on the embodied, temporal, performative and experiential aspects of interaction, such as the tangible, social, embodied interaction that Dourish (2004) outlines, has shifted the conceptual and methodological focus of design away from the visual. This move favours seeing design as emerging "from the shadow of our preoccupation with 'visual symbols'" (Buchanan 2001:11) or sees interaction as 'occupying time' (Mazé 2007). In Garrett's (2002) popular model of user experience, the design of visible interfaces is compartmentalised into the separate domain of 'visual design', distinct from interface or interaction design that concentrate instead on flows, movement and structure.

Hallnäs & Redström (2006) frame interaction design as "a shift of focus from what a thing does as we use it to what we do in the acts that define use, and from the visual presentation of spatial form to the act presentation of temporal behaviour." (ibid:23). This move towards designing the acts and temporal behaviour that defines the intended use of things and systems is a strong move away from the visual. As an example of experimental design methodology they present a project that attempts to remove the dominant visual expressions of design entirely, by staging "The Dark Room Fashion Show' that asks fashion designers to 'concentrate on *something else* in the process of designing"

(ibid:187). Interaction design practice has also focused on other means of developing interaction such as experience prototyping (Buchenau and Suri 2000) and 'epistemic action' (Klemmer et al. 2006), approaches that emphasise designing with physical media and the performative expression of tacit knowledge.

These framings are necessary in the face of previously dominant visual approaches in design, they exemplify the ways in which interaction design addresses concepts beyond visual or physical form. However, by downplaying the visual in interaction, these approaches risk overlooking the significant ways in which visual mediation and communication constitute and inform these 'acts' and 'behaviours' of interaction.

This conceptual and methodological move away from the visible in interaction design mirrors some of the developments in HCI and ubiquitous computing. The discourses of invisible and seamless computing, as outlined in Chapter 2, represent a similar move away from seeing interaction with computers as a visible phenomena, and an emphasis on deliberate 'making invisible'. Bell and Dourish (2006) find that ubiquitous computing research has focused on particular visions of seamlessness and invisibility that have distracted from seeing the formation of alternative, and visible, kinds of interaction:

> our failure to notice the arrival of ubiquitous computing is rooted (at least in part) in the idea of seamless interoperation and homogeneity. It turns out instead to be a messy one. Rather than being invisible or unobtrusive, ubicomp devices are highly present, visible, and branded. (Bell & Dourish 2006:142).

They identify that computation is already highly ubiquitous, in heterogeneous and messy ways that were not necessarily predicted by ubiquitous computing researchers. These technologies and infrastructures are "highly visible in terms of the range of concerns to which users must be oriented." (ibid:142). For instance a ubiquitous computing technology like public WiFi is branded through recognisable symbols such as the WiFi symbol that represent the nearby potential of internet access for computing devices. Although this symbol has become relatively stable, it represents a complex set of systems that must be engaged in ad-hoc ways, through different service providers, identity management, sign-in mechanisms, payment models, etc. Visual symbols for WiFi play an important role in our use and experience of spaces, cities and of the infrastructure itself. They signal "not only their functional relations but also a set of connotations of about technology, identity,

and identification" (Morrison and Arnall 2011), where they may provoke curiosity or connote a certain cultural image, such as the use of WiFi as the dominant feature of the branding in Figure 22.

Figure 22. Advertising using the WiFi symbol for free internet on a commuter train in Copenhagen, Denmark.

In industrial and product design the notion of product semiotics has developed from earlier theories about product semantics. Product Semantics was a theory developed by Krippendorf and Butter (1984) that emphasises the aspects of communication and meaning (semantics) in products. In product semantics there is the concept of the product as a text that can be read with various levels of socially constructed meaning. Vihma (1995) attempts to enrich these perspectives by taking the icon, index and symbol and creating guidelines for the analysis of products based on these concepts. But Hjelm (2002) finds that these applications

of product semantics are too narrow to provide frameworks for analysing designed artefacts in a cultural context, and instead argues that we should instead look towards contemporary semiotics theory:

> Contemporary Semiotics have moved away from the classification of sign systems to study how meanings are made and are not only being concerned with communication but also with the construction and maintenance of reality. Studying semiotics can assist us to become more aware of reality as a construction and of the roles played by ourselves constructing or designing it. It can help us understand that information or meaning is not 'contained' in the world, in books or products. Meaning is not 'transmitted' to us – we actively create it according to a complex interplay of codes of which we are normally not aware. (ibid:2)

Julier (2006) critiques views of design that situate designed things as objects to be read as 'texts', and instead calls on a richer understanding of design culture:

> Culture is no longer one of pure representation or narrative, where visual culture conveys messages. Instead, culture formulates, formats, channels, circulates, contains, and retrieves information. Design, therefore, is more than just the creation of visual artifacts to be used or "read." It is also about the structuring of systems of encounter within the visual and material world. (Julier 2006:67)

In summary, interaction design increasingly involves more than the creation of visual symbols for graphical interfaces. This is particularly pertinent as we move from screen-based interfaces towards tangible and embodied interaction through interfaces such as RFID. Yet there remains a fundamental part of interaction design that involves the visualisation and communication of complex systems to users. Visual representation of interface technology, even invisible, ubiquitous interfaces such as WiFi, is still an important part of the experience and explanation of that technology in the landscape of advertising and branding. The shared meanings of emerging technologies such as tangible, invisible, ubiquitous computing interfaces are still not established. As identified by Hjelm (2005) the communication of the function, meaning and implications of an invisible interface technology should be of particular concern to interaction design and HCI. The creation of visual abstractions of computational behaviour, of marking and signalling interactional possibility, remain important aspects of the design of many interactions.

The visibility of design processes

As well as making objects and interactions visible, there is much research about the visible nature of design processes, and of how visual media is used as part of design practice. Design and innovation processes are now highly complex technical and social processes, so finding models of communication to represent this complexity has been a challenge for more sociocultural and humanistic oriented design research. Bucciarelli (1994) says that the design process attempts to achieve "consensus among participants with different "interests" in the design" and that these interests "are not reconcilable in object-world terms (ibid:159)". In this way the design process becomes about discourse, communication, rhetoric, negotiation and compromise, and shaping a "common structure, shared by all participants across object-worlds, for patterning explanations and fixing what counts as an explanation of consequence." (ibid:81) Sketches, diagrams, images and prototypes then become rhetorical tools, 'short vignettes' with which to articulate justifications for the way in which an object will function or perform.

Models of communication as a process in design have been explored particularly in engineering design, where communication has been seen as one of the critical factors in the success of a design process (Hales 2000). As noted by Hallnäs and Redström, interaction design is often a "link between basic research in computer science and product applications" (2006:25). By acting in-between complex and highly technical disciplines and cultures of use and application, interaction designers adopt positions where translation and negotiation through visual representations is a central practice.

Henderson (1999) reveals a particular engineering visual culture, "a particular way of seeing the world that is explicitly linked to actual material experience in rendering that world" (Henderson 1999:9). From an engineering perspective (Maier et al. 2005) attempt to find a meta-model of communication that provide for a richer understanding of communication in design by using Luhmann's concept of communication as *information, utterance and understanding*. The key difference here is that the emphasis in Luhmann's model is weighted towards the 'listener', where it is the 'listener' that decides on the meaning of the message not the 'sender'. By opening up for *interpretation, understanding*, and even the possibility of a rejection of the intended meaning, Luhmann reverses the perspective of the sender-receiver model. This perspective sets up communication as a highly complex and difficult process, the ability to account for interpretation, ambivalence and unpredictability in communication that has uncertain outcomes.

Maier concludes by saying that design is a process of collaboration and negotiation that relies on communication as a foundation.

Communication as process has also been taken up by others in human-centred design, such as Roschuni et al. (2013) who propose techniques for communicating design research findings by using ethnographic methods to study the potential audiences for the communication of design research. They see the mechanistic model of communication as "obscuring important issues in cross-team and cross-discipline communication, such as those of interpretation, negotiated meaning, and resistance to new information. (ibid:7)

Folding the concept of the epistemic artefact back into design research Ewenstein & Whyte (2009) suggests that visual representations are pivotal to knowledge practice in design. They propose the concept of a "trans-epistemic object" in design, to account for the multiple roles that visual representations play through the knowledge generating processes in and across design communities. They characterise trans-epistemic objects as shifting and changing over the course of a project, in what they relate to an 'unfolding ontology':

> Visual representations as 'artifacts of knowing' are characterized by an 'unfolding ontology' (Knorr Cetina 2001) – they are constantly in flux, rather than fully formed. Their emergence and use gives rise to a range of questions that demand coordination and collaboration across domains of knowledge or epistemes. (Ewenstein & Whyte 2009:9)

Drawing on Knorr Cetina's concept of the 'transepistemic' they arrive at this notion of trans-epistemic artefact by recognising that visual representations in design are defined by their openness, their "lack in completeness of being" and their "capacity to unfold indefinitely" (Knorr Cetina 2001:181).

In design there are multiple studies of the use of visual representations as essential to design's communicative practices. For instance Lim et al. (2008), Stacey et al. (1999) and Bertel (2006) look at sketches as the foundations for exploration and communication for professional designers. Interaction designers communicate their concepts and decisions through sketching and prototyping to "frame, refine, and discover possibilities in a design space." (Lim et al. 2008:2). Both Stolterman (2008) and Wakkary (2005) look at sketching as a designer's means of framing complexity, in particular as 'a mode of

experimentation' (ibid:67). Drawing upon Schön's notion of reflective practice, Wakkary finds that a designer

> functions by going back and forth between construction and reflection as a means to understand the designer's situation she is creating, hence the notion of the designer as having a 'reflective conversation' with the situation. (Wakkary 2005:68).

Buxton (2010) devotes an entire book to the art of sketching in interaction design, specifically the sketching of 'user experiences'. In this handbook, visualisation techniques are explored and compared, from line sketches to animation. Line sketching affords the designer a quick way to explore graphical style, functionality and the flow of interaction, but is limited in its ability to capture "time, dynamics, phrasing, the temporal things that lie at the heart of the experience." (ibid: 279). In contrast, animation can be used to "explore and illustrate the dynamics and character of a potential interface, transaction or experience." (ibid:299). However, as is noted later, the time and effort involved in animation can be too great to afford the kinds of reflective, back and forth conversation that is required in exploratory, idea-generating design processes.

Visual culture and media

If we are to understand the ways in which design research may work beyond its disciplinary boundaries, how its practices and outcomes might engage in popular culture, then we must turn to some concepts of visual culture and media studies.

Design is most often employed in the service of commercial, market and industrial needs, to shape the products and services enabled by new technologies, but also in shaping the packages through which technologies stage symbolic contests over which one will prevail. Product and interaction designers shape the way that, for instance, a new mobile device or tablet is both formed and used. Designers are also involved in the ways that those devices are represented, through audio-visual and narrative means, designers shape the meanings and mythology around new technology. Nye (2007) makes the case that technology itself is in fact the intricate connection between narratives and tools:

> Making a tool immediately implies a succession of events in which one exercises some control over outcomes. Either to tell a story or to make a tool is to adopt an imaginary position outside

> immediate sensory experience. In each case, one imagines how present circumstances might be different." (ibid:3)

Designers are also involved in more speculative work, in proposing and communicating designed products and services that don't yet exist, as in the case of Microsoft's *Office Vision* (2011) and Corning's *A Day Made of Glass* (2011). These 'vision videos' are created and staged to generate interest in an industry or a product, or to perform and script emerging or new domains that are not yet fully formed. They are designed and produced to reach large audiences, but specifically to appeal to designers, technologists, and so-called 'early-adopters', consumers with a keen interest in the bright, new and emergent. Here the designer's role (or visual effects artist's brief) is the creation of empty signs, defining the surface characteristics that connote a potential for (without defining the specifics of) new technological systems and implementations.

In popular culture and media the discourse around technological change occurs in many fields: the representations, meanings and interpretations of new technologies are debated in politics, the news, the subject of heated discussion online, and as plot devices and props in narrative media. How is new technology represented, perceived and understood in popular culture? In their investigations of the media discourse around nuclear power Gamson & Modigliani (1989) find that policy issues like these have a culture, an "ongoing discourse that evolves and changes over time, providing interpretations and meanings for relevant events" that includes "metaphors, catchphrases, visual images, moral appeals and other symbolic devices that characterise this discourse." (ibid:2). In these cultures, visual images "do not have a fixed meaning. People approach them with some anticipatory schema." (ibid:18). We also don't encounter these things as individual items, but as 'interpretative packages', and in any debate in culture there are competing packages that "ebb and flow in prominence and are constantly revised and updated to accommodate new events." (ibid:2).

The lack of popular, public discourse around invisible technologies like RFID leads again to Hjelm's double-invisibility, both the material phenomena and their cultural implications are hidden. Market-driven, technical viewpoints and popular cultural mythology have therefore dominated the discourse around contemporary technology. The marketing, hyperbole, myth and misunderstanding from popular media has come to define the discourses around technological change.

As we saw with RFID earlier in this chapter, when we observe new technology discussed in popular media, it is polarised either towards positivist views of technological change driven by marketing and engineering, or as negative, reactionary views expressed by protest groups, popular media or government. There is little ground for discussion of the material basis for these arguments, for exploring how the phenomena of interface technologies might support for or constrain these perspectives.

Contemporary everyday life is carried out in an intensely technologically mediated culture. How should interaction design research engage with the popular cultural imagination of new and emerging invisible technology, and intervene in its understandings? How might we apply design's practice of material exploration and visualisation to emerging technologies? Visual design and visualisation approaches may be more important as we move towards interactive systems that are conceived of as invisible or 'seamless'.

Critical design

One specialisation of design research that has attempted to directly approach visions of emerging technology is critical design. The term 'critical design' was introduced in Anthony Dunne's book Hertzian Tales (1999) and describes a design process that use speculative design proposals to challenge assumptions, preconditions and givens in technological systems (Dunne & Raby 2007). Critical design can be defined as a form of design that uses the processes, tools and languages of product and interaction design to not solve or resolve problems, but to critically rethink the parameters of the problem area itself (Mazé & Redström 2007). Seago and Dunne describe the key methodological factor in critical design research as

> using the process of invention as a mode of "discourse", a poetic invention that, by stretching established conventions, whether physical, social, or political, rather than simply affirming them, takes on a radical critical function, a material critical theory, or what Dunne terms a 'parafunctionality'. (Seago & Dunne 1999:17).

There are perhaps two things to take up from critical design. One is that critical design sets itself up in opposition to the dominant design and technological discourse and rhetorics. In doing so it takes up technology

itself, in order to create new perspectives on it. We see this in critical design projects that have looked at for instance radio (Dunne 1999), nanotechnology and biotechnology. Some have extended the notion of critical design to the concept of 'adversarial design' (Di Salvo 2012) that specifically reinforces the protest in this oppositional or adversarial position for design.

The second point to take up from critical design is its methodologies and approaches that include the concept of 'object as argument' and a fundamentally communicative research practice. The idea that the designed object can be created as an argument has been taken up by many in design. Krippendorf finds that "designers weave sketches, drawings, models, prototypes, and experimental evidence into their arguments" (Krippendorff & Butter 2007:17). Danholt focuses on the performative aspects of prototypes in design, and the ways in which prototypes are material things that prescribe, animate and produce specific kinds of subjectivities, bodies and agencies:

> Prototypes are not inanimate things that assist us in the design process as resources for users and designers to use and discard. They make people do things. They design people in the process. People are the actual plastic and adaptive components in a design process, not the prototype. (Danholt 2005:7)

Although it is not explicitly noted within critical design, and the mediations and visual cultures are under-analysed, the use of photography and film is central in critical design practice. Dunne sums up some of these approaches in his description of the design object as prop:

> By abandoning the technical realism of the prototype and the visual realism of the traditional industrial design model, conceptual models in combination with other media, can refer to broader contexts of use and inhabitation. For instance, by using conceptual models as film props the viewer can be drawn into the conceptual space of the object in use rather than an appreciation of the thing in itself. (Dunne 1999:92).

Before critical design, design has a tradition of working towards the popular imagination as far back as the '70s with the Milan school (Lang & Menking 2003) that engaged in a critique of dominant thinking and modes of representation in architecture. More recently critical design has taken the role of critiquing the dominant, normative approaches to

technology and electronic products (Dunne & Raby 2001) through the design and exhibition of devices and objects.

Critical design is a form of design that uses many of the practices and tools of product and interaction design to not solve interactional or user-centred problems, but to critically rethink the parameters of the problem area itself (Mazé & Redström, 2007). Critical design was developed with a focus on critical practice where "a pragmatic conception of reflection is extended as a critical modality - to question and transform rather than only describe and affirm" (ibid: 10). Critical design, therefore, provides an analytical stance and design approaches for exploring, conceptualising and communicating around emerging technologies.

Critical design is often oriented towards critique of technological implications, through fictionalised scenarios and objects. It also focuses attention on the final artefact — a set of objects in a gallery, a well-photographed product, or an intervention or installation. These artefacts are often obscure, evocative and intriguing, often accompanied by essays explaining the work. As users, or audience, for these objects we are expected to derive or imagine meanings from our direct experience or from their representations. They don't necessarily offer a direct relation to the concepts or ideologies they represent. For instance, Dunne and Raby's Faraday chair offers a 'radio-free zone' in which users can escape from the everyday bombardment of radio waves, a tiny vacuum in the hertzian landscape. Its bare, physical form could be mistaken for an IKEA coffee table, but it connotes a feeling of encapsulation through the photographs of people lying inside the object, but without reading the accompanying text, and without prior knowledge of a Faraday cage, we must do a lot of interpretation to make sense of its meaning.

The outputs of industrial, interaction and communication design work such as models, visualisations and products/objects can be seen as rather declarative, making concrete statements about how the world should be. Similarly, critical design work is also highly declarative, in the creation of designed objects that are statements about the world. How do we instead design a kind of design that is more generative, discursive, that imparts open-ended questions? Is there a design that is a mode of 'discourse', that may be as much about extending the possibilities and opportunities in technology and inventive practices as it is about critiquing dominant positions?

In summary, although critical design has opened up a space for reflecting on technology and its discourses, and has exemplified some mediational

and communicative practices in design, it has not yet opened up reflections on what this means for design practice and for design research. What does it mean to engage with technological materials and its discourses directly in design, rather than products, clients and users? And how can we reflect on and take up these mediational, communicative and discursive practices and approaches?

Design and articulation

In all of these perspectives, we miss an approach to seeing how an emerging technology like RFID is engaged by design, not just in an analytical way, but as a generative, productive, constructive practice. Through all of these perspectives, how does design intervene in shared cultural symbols and meanings around technology? What are the approaches to designing technologies through these various interaction design, technocultural, and sociocultural means?

Hall's notion of articulation describes the kinds of mediation that takes place as part of this kind of design practice. Grossberg uses articulation to describe the drawing together of various ideas, people, groups, economic arrangements and means of production for the "production of identity on top of differences, of unities out of fragments, of structures across practices" (Grossberg 1992:54). Slack says that epistemologically, articulation is a way of "thinking the structures of what we know as a play of correspondences, non-correspondences and contradictions, as fragments in the constitution of what we take to be unities." (Slack 2005:114). Through the concept of articulation we can analyse how individuals or groups may coerce different sorts of objects to act or envision themselves as a group. Importantly, the concept of articulation focuses on contingent practices rather than general ideas or economics, making it useful for situated and specific understandings of culture.

For interaction design research, articulation may help understand how we forge various alliances with other groups (such as HCI, engineering and STS) and how we bring together cultural tropes, materials and mediations in order to create new objects with new meanings. Talking about designing in technoculture, Balsamo notes "innovation is performed through acts of articulation" that "draw on understandings that are already in circulation within the particular technoculture of users, consumers and participants". As design researchers we are active in articulations of our interests, alongside others with various perspectives on technology, to act with or against the dominant,

entrenched technology discourses and mediations. What kinds of alliances and assemblages (to use Latour's terminology) are we drawing together as designers in order to address these networked cultures?

Designer researchers draw together a range of groups, objects, discourses, materials, and media in various assemblages and alliances to address the cultural understandings of new technologies. Part of design practice is the study, collection and re-use of existing cultural objects and media. Articulation can provide "strategies for undertaking a cultural study, a way of 'contextualizing' the object of one's analysis" (Slack 1996:113) where those objects might be existing designs already in circulation in culture, media representations or advertising of new technological products, or even one's own new designed objects. In this way articulation provides a strategic mechanism "for shaping intervention within a particular social formation, conjuncture or context." (ibid:112).

Bringing material and mediational together

Why combine design mediation and material-centric perspectives? Central to the fictionalisation and myth-making around RFID outlined above, is the misunderstanding and the slippery, fluid notions of what constitutes the materiality of RFID technology. What enables a linkage between a passive RFID tag that has a reading range of about 10cm, and GPS technology, that works on a completely different infrastructure, wavelength and works over hundreds of kilometres? I suggest that our experience of radio technologies, all the way from tuning an analogue radio, to having an anti-theft gate in a shop squawk at our mistakenly scanned goods, to using an Oyster card to having GPS locate our mobile phone suggest that the affordances of radio technology are vast and fluid. Even when we understand that these technologies have boundaries and limitations, they seem to work 'magically' just enough, that we are willing to suspend our disbelief and imagine them all talking together. Without good explanations, or a solid technical knowledge of the standards, protocols, radio spectrum, etc. we are unable to sensibly and coherently analyse or deconstruct how the technologies are different, what their affordances actually are and how they might be similar.

Speculative design practices such as 'design fiction' and parts of critical design are often removed from material practices and the material realities of technoculture. As mentioned above, 'vision' films for new technological products often only hint at the surface detail of systems

and product implementations. They contain empty signifiers, at the highest level of abstraction, that don't need to relate to the ways in which an interactive system would work. They have not had to explore the technological materials, and their relationship to interaction, use and context. It leaves many of these vision pieces in the position where they can only speculate on the surface, without the substance to add to a rich debate about the future of technology.

Designed objects are complex compositions of materials and mediations. The meaning of an object is made up through this composition. From an analytical perspective in interaction design Hallnäs (2011) recognises that the expression of an object is made up of its materials: a composition of form and expression. The use of a designed object cannot be separated from the media that we have experienced around it, whether that is advertising, reviews, our friends comments on social media or through journalism. So our objects don't just have meaning for us through their 'product semantics' but they are also wrapped with their associated meanings from media representations.

In the next chapter I explore the mediational material approaches to RFID that take up these concepts and themes.

Chapter 3
Approaches

In this chapter I begin by setting the context of practice-led interaction design research, in which the design practice informs subsequent research, reflection and analysis. I then describe the approaches I took to RFID along each of the three analytical and productive themes of mediational materials. I then look at how these same approaches have been appropriated by other designers and researchers, and how they have been applied to other emerging technologies.

Practice-led interaction design research

This research is led by practice: studio-based interaction design involving the design and development of technical experiments, prototypes and creative media production. As such, it did not begin with a dominant research perspective or approach. Although it initially emerged from HCI perspectives, we used interaction design practice to move away from those dominant approaches, and to find and inform our subsequent research. In the later stages of the project it became 'research by design', where our large body of design practice was used to provide research material that shed light on the dominant technology and research discourse.

Practice-based design research generates knowledge from the production and analysis of designed objects, interfaces and media. It has a long tradition, but I follow the characterisation of it as 'research by design' identified by Sevaldson (2010). In research by design the design practice is a theory building activity: engaging as designers in design activities where 'investigations are conducted within a first person perspective combined with a reflexive mode making design knowledge explicit' (Sevaldson 2010:2). According to Löwgren & Reimer (2013) these approaches are "characterized by the emphasis on design practice as part of the knowledge production processes." The contributions from practice-based interaction design research include design knowledge that

> can be appropriated by other designer-researchers and used generatively as well as analytically and critically. (Löwgren & Reimer 2013:98)

Much research in this direction is focused on generating insights and understandings of users and user contexts. Studies such as these build knowledge through designed objects, through the 'critical artefact methodology' proposed by Bowen (2009) or through 'probes' used to uncover issues and problems through user studies (Gaver et al. 2004). They might also be used in the process of 'problem-finding' such as the ambiguous film scenarios used by (Briggs et al. 2012) to uncover existing problems and concerns with imagined technologies. Designed objects enable a kind of "conceptual modelling", objects as a "material thesis", in a practice of "socio-aesthetic research" (Mazé 2007). There is also a need to consider experimental, inter-disciplinary practice and research in design as a method of knowledge building. As Mainsah and Morrison (2013) put it:

> design research may benefit from investigations, explorations and innovations in the means of conducting and of conveying design research from qualitative methods in the social sciences. [...] we see a need to more fully consider the production of knowledge by designing and via the acts of constructing of design artefacts. (ibid:153)

In research by design, objects are epistemic artefacts, knowledge carrying or generating, and can be trans-epistemic in the way they carry knowledge across disciplinary boundaries. But in the descriptions and accounts of much research by design mentioned above, the communicative, mediational, reflexive qualities of the research object are almost always secondary to the production of an artefact. They focus on the analysis and reflection on the design of an object whose primary purpose might be a usable interface, an efficient system design, or new kind of user-experience. But what if the mediational, communicative, reflexive qualities of a designed artefact was the primary aim, objective and approach in a research by design approach?

In this chapter I outline in detail the three approaches that build knowledge of RFID as a mediational, communicative, cultural phenomena. In this I want to extend the notion of the 'knowledge generating, epistemic object' in practice-based interaction design research to include the mediational material that we analyse and develop as interaction designers. I split the mediational material approaches into three kinds of outcome: the results of the study of the cultural context for design, the exploration and creation of technical materials and the mediational, communicative artefacts produced in this process. Like

Mainsah and Morrison, I'm interested in extending the boundaries of methodological experimentation in interaction design:

> the importance of methodological innovation that allows design research to look into its practices, academically, productively and through situated application." (Mainsah & Morrison 2013:161)

Here I'm particularly interested in creative, inventive, mixed methodologies and approaches to the ways in which interaction design engages with the culture, material and mediation of RFID technology.

Approaching RFID as a mediational material

As the previous chapter outlined, this study is situated in the cultures, materials and mediations involved in the emergence and disappearance of technologies like RFID. In order to engage with this change, and to study its meanings, we need to take a number of approaches that range from design research to HCI, STS, cultural studies of technology and ethnography.

Central to this thesis is the three interlinked approaches for interaction design to engage with culture, material and mediation. Although it draws upon a similar constructivist approach to knowledge building, it does not take Actor Network Theory (ANT) or Science and Technology Studies (STS) as its starting point. An STS approach to RFID might offer an account of RFID systems, their behaviours, networks and phenomena and scrutinization of how we talk about them, and what this talking or language makes possible. Through this discursive boundary work they would tackle the question of how systems are and get to be composed, such as John Law's study of aircraft (Law 2002). Instead the approach taken up here actively constructs objects, visualisations and perspectives through processes of design. These objects are used to reflect on the technologies, networks and phenomena that make up our shared technoculture. These mixed, trans-disciplinary approaches work through the three broad, inter-linked domains outlined previously.

These approaches together are designed to be able to interrogate and shape the meanings of emerging technologies like RFID. I aim to embed the concept of the technocultural, of mediational and communicative issues into interaction design practice and research. That entails taking up existing discourse, cultural themes and tropes, materials, shared

symbols, meanings and communicative qualities into the design process. These things are taken up and shaped, alongside an exploration of the technology as design materials, and made into new assemblages of meaning, and then articulated through communicative, discursive means.

A cultural studies approach in design will only get us so far in understanding the existing meanings and interpretations of technologies. With emerging technology we can't just do a semiotic or media-studies analysis of existing interfaces and media, because much of the use, interpretation, phenomena and material doesn't exist yet. There is also a need to reveal the phenomena and materiality of the technology, and to speculatively interpret and design with it, in order to uncover latent meanings and understandings. In order to explore, experiment and understand an emerging technology like RFID, we need to do many things: to take account of its existing and related meanings and mediations in culture, to explore it as a material with hidden phenomena that must be revealed, and to find new articulations, languages and visual representations in order to share our understandings and perspectives.

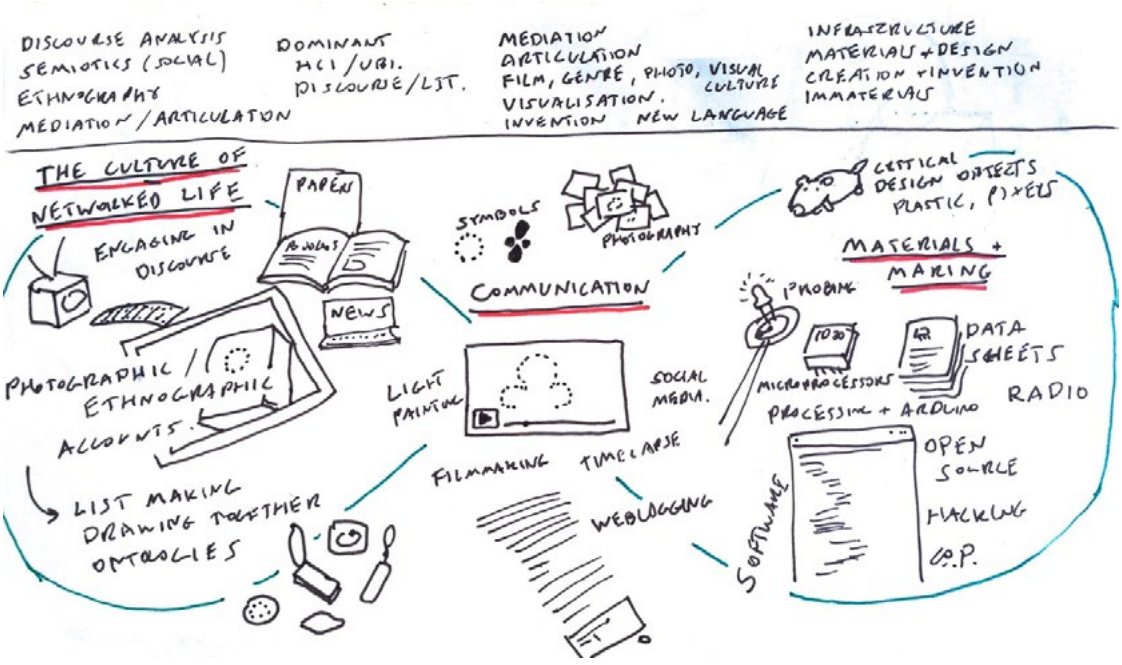

Figure 23: An early sketch of the networks and relationships between objects, practices, people, and modes of analysis in my design process. This led to the model in Figure 9.

Figure 23, above, is one of the initial sketches of the objects that are assembled into our design practice, loosely organised into three parts: the investigation of culture on the left, the communication in the middle, and the materials and making on the right. The diagram was sketched in order to show the richness and diversity of these design approaches, it is a dense assemblage of wildly different yet tightly knit objects, meanings and practices.

These approaches are connected in order to engage in a design process along the lines of what Ward and Wilkie (2008:3) describe as

> to go out, open the black boxes and untangle the complexities and novelty [...] in doing so provide their own situated and partial descriptions and new design contexts.

In design practice and research there are mixtures of approaches that can do this as I will show in the next chapter. It is a kind of inter-disciplinary research by interaction design practice that engages with technoculture through design research techniques, a deep knowledge of technical development and prototyping, and an ability to creatively communicate about these matters. It involves a community of practice that includes elements of design practice, critical, discursive and adversarial design, creative technical development, alongside media, advertising, filmmaking and cinema. These activities can be combined into approaches that create cultural-technical artefacts that perform through film and through online media, but also artefacts and prototypes that work and function, that perform in the hand and through knowledge of technical materials and phenomena. By articulating a mix of these practices together, we can begin to see the approaches where design may intervene in understandings and meanings of technology in culture.

In the introduction I offered an abstract model of discursive design research (see Figure 9) that involves engagement in culture through its discourse, both analysing and producing communicative artefacts through a process of making. In this chapter I expand on this model and its inherent approaches and activities.

Visual research of RFID

In the first of these three mediational material approaches I develop methods for engaging with technocultural phenomena based on visual research methods from design, ethnography and cultural studies. Although visual research is a key feature in many design practices, particularly in graphic design and advertising it is hard to find research

accounts of this activity, or to find ways to frame and analyse it as part of interaction design research. In their handbook of visual research Noble and Bestley (2007) find that although it is common for designers to conduct visual research, through widely known practices of material gathering such as the creation of 'mood boards', a more rigorous framing and methodology for this practice is required. They define visual research as a means for designers to build knowledge about existing visual languages, understandings and expectations from a potential audience:

> It is important for the designer to understand the range of visual languages and texts which already exist in the space that the proposed design will occupy. All audiences have expectations with which they will interrogate and interact with visual messages—the aim of innovative design is to relate to these already familiar forms, and to extend the visual language used in new and exciting ways." (Noble & Bestley 2007:87)

The authors then go on to outline basic communicative, semiotic and cultural theory and practices that underlie this visual approach. What is significant here, however, is that although this emerges from a different analytical tradition, it is clear that there is a relation between this and the concepts of remediation or technocultural reproduction. The processes of visual research in visual design align closely with these analytical approaches that are concerned with how existing cultural meanings are taken up in new objects. What I describe over the next few pages is a process of visual research that directly addresses the ways that the meanings of RFID are constructed, remediated and reproduced through their visual representations.

Figure 24: Collecting commercial literature about RFID products, here an 'RFID security wallet' offers to 'keep your credit card & personal information safe from digital pickpockets'.

In the early phases of the Touch project I used exploratory research methods to explore and gain understanding of the existing cultural manifestations of RFID. As outlined in the introduction and background, RFID is a technology that is already widely in use in different parts of the world, for many different kinds of interactions with products and services. The process of investigation and exploration then involved travel to countries and particularly cities where RFID was in active use. The research took us to Seoul, Paris, New York, London, Helsinki, Milan, Rome, Barcelona and Riga to name just a few places. These trips often had multiple purposes, we were often travelling to speak about the project at conferences or to participate in workshops. They were also used to collect the marketing material from technology and engineering firms, and to

study the media narratives and folk-mythologies around RFID in popular media. This created an informal body of photographic references such as the image in Figure 24, above, that were tagged and archived using Flickr, in order to create a dynamic, social and continuously expanding resource for myself, my colleagues and research partners, and for the various design and technology communities I participated in. In Flickr we discovered a "key means to also externalising our own design thinking and processes." (Morrison et al. in press).

There were always two distinct research activities that were pursued in order to explore the technoculture of RFID in these different locations. These activities were conducted in order to build knowledge about the cultural and visual mediation of RFID technologies across various cultures.

The first of these activities was engaging in various RFID interfaces, systems and infrastructures. I sought out transport and payment systems where RFID was being used, and found out how to become a 'user' of these systems. Where appropriate I would also talk to bus drivers, ticket agents, shop-owners, passengers and others that were found engaging with RFID systems. This was to explore the interactions, systems and services of these interfaces, to uncover their different design approaches, to find interesting or novel implementations and architectures. We could think of this as an investigation of RFID as a tool and a system of interactions. This research found that there were pop-up markets in Seoul that offered same-day printing of custom RFID travel cards, showing a desire to visually customise these everyday objects (see Figure 25). It revealed that the RFID provider 'T-Money' in Seoul would provide blank RFID cards to these vendors, supporting these small-scale, bottom-up customisations.

Figure 25: A market stall in Seoul, South Korea that offers customisation of 'T-Money' RFID travel cards. Here seen drilling the keychain hole in a custom travelcard with a printed photo by the author.

The second activity was to reveal the visual mediation and communication of RFID by photographically documenting the visual representations of RFID interfaces. This was to build a resource, a wide-ranging archive of the existing visual representations of RFID, from which we could build knowledge about how these interfaces are understood and represented through visual symbols such as the RFID interface in Figures 26 and 27.

Figure 26: A 'RIcaricaMI' RFID reader on the ATM transport network in Milan, Italy. The use of the term 'Qui' or 'Here' reveals the spatial aspects of RFID interaction.

These instances of RFID readers, RFID tags, RFID advertising, marketing and instruction were sought out and documented. Using photographic techniques such as architectural or street photography helped to set the interfaces in their context, they did not just focus on the interface, but on the interface and its surroundings. I thus built a large archive of the ways in which the invisible, hidden aspects of RFID had been visualised and represented in different ways in different places.

Together these visual research practices built a body of knowledge about both the interactional and the mediational qualities of RFID interfaces and implementations around the world. By doing this research in different cities I uncovered different perspectives on how the technology

was implemented and different approaches to how the invisible, systemic aspects of the system were represented.

Figure 27: An RFID reader installed at turnstiles on London's Underground system, UK. The image of a card being visually 'swiped' across the bright yellow background offers instruction for how to validate an RFID ticket, while the small, green LCD screen behind provides otherwise invisible information as to the validity and value of each ticket as it is swiped.

Here I treated RFID interfaces as tools wrapped in signs. In this way we can see interfaces as instances of mediational material: as technical interfaces that are also cultural artefacts that can be read, interpreted, critiqued and developed through their visual representations.

As this research progressed, many RFID objects were collected and laid out against a white background in a single photograph. The objects

ranged from a London Oyster Card, a set of raw RFID transponders in clear plastic, to custom-designed travel cards from Asia (with both personal images and branded with Adidas logos) and a child's toy hippo, with a USB interface for topping up the money on the card as seen in Figure 28 below.

Figure 28: Collected RFID tags laid out on a white surface.

The image in Figure 28 was set up, in a photographic studio, to reveal the diversity of forms and visual representations that RFID technology already takes in the world. Counter to ubicomp's dominant future-tense, a permanent 'proximate future', this was a visual argument that RFID is already used for many purposes, personalised and highly branded. In this sense they can be looked at as an articulation of a material and mediational perspective on RFID: a group of objects forced together to

argue for a perspective on RFID technology as messy, ubiquitous and highly personal.

This colourful, playful image has been appropriated into many different contexts, from student presentations, to keynote speeches about the internet of things. It also features on the first two pages of a Google image search result for 'RFID tags' and is also amongst the highest ranking 'explore' images of RFID on Flickr, which indicates the amount of conversation, comments, links, and views that the image has compared to other images of RFID. In this way we used photography to articulate our interests in the technology, in opposition to existing industrial and marketing views of the technology, and to build shared, community interest. In this explorative approach to RFID, photography is a means to discover and propose new perspectives on the technology.

I also looked at aspects of RFID interfaces as instructional or information graphics. Figure 29, below, shows the multi-modal explanation of RFID interaction with the *T-Money* system in Seoul. The explanatory text in two languages, the distinctive image of a *T-Money* travel card, and the life-size diagram of a hand placing the card into the 'sensor zone'. This reveals many things, one is that the system is used by locals and tourists, so language is an issue. Another is that clearly RFID interaction is not 'natural' or obvious, it must be instructed through the use of text and visual diagrams. Yet another is that the designers felt it necessary to explain RFID as a 'sensor', with a 'zone' in which that sensor functions, an interface that required technical and spatial description.

Visual design analysis

Figure 29: Instructional graphics and text on a T-Money RFID turnstile in Seoul, South Korea.

In instructional design, the practice of the visual designers is to understand, interpret and explain the complex features or systems of products and services through developing visualisations and 'visual function' (Mijksenaar 1997). Designers Mijksenaar and Westendorp (1999) playfully reveal over a century of visual instructions, and reflect on the contemporary need for visual communication of technology:

> How do we cope with these complicated products and features? We learn to read instructional hieroglyphs. Mass production, mass consumption, high-tech electronics, the do-it-yourself industry, the development of packaging (for almost everything) and the growth of international transportation and trade have urged the

> development of universally comprehensible language: visual instructions, the imperative pictorial Esperanto of our time. This language has flourished in a century of visual entertainment, of movies, television, illustrated magazines, cartoons. Visual communication in general has triumphed over text.

I treated RFID as an emerging technology that could be investigated as designed signage and typography as a kind of 'way finding'. Design has a long history of making the complex structures of cities visible and understandable to its population through signage systems and way finding (for histories and explanations see Mollerup 2005, Baines & Dixon 2003). In these practices there is a great deal of attention to clarity, legibility, cross-cultural communication and to the systemic aspects of visual design production. For instance the road signage system designed by Calvert (documented by Baines & Dixon 2003) was designed as a visual system with rules and guidelines that could be applied to the enormously complex system of road structures in the UK. By looking at RFID systems as signage we could investigate how they were communicated, how the invisible complexity was made visible, and how this created new and alternative meanings about the technology.

Figure 30: Advertising for 'Visa Wave' RFID-based credit cards in the UK.

In Figure 30 above, we see advertising for contactless, RFID-based credit card payment that can be used to make small payments by 'tapping' or 'holding' the credit card on a reader, and without entering a PIN number. In this case, the photograph is taken at a drive-through McDonalds in the UK, a place where speed and efficiency of payment are functional priorities. The use of 'contactless' as persuasive, marketing language here evokes the idea that we don't even need to make contact to make payment, it connotes speed, efficiency, perhaps even cleanliness. The visual use of concentric lines emanating from a single point reproduces existing visual language for wireless systems such as WiFi, while the diagram of the card and the hand expresses the actual gesture of 'contactless' touch required to achieve a transaction.

Figure 31: The remediation of an existing symbol of a physical key to explain the access-control function of an RFID entry system.

RFID interfaces remediate existing forms of interaction and meanings in their visual representations. They fold into their graphic language existing themes of ticketing, cash transactions and physical exchange. Given that RFID is an invisible technology, and there is no button, slot or mechanical interaction, designers clearly feel the need to make the interaction points visible through colour and shape, and through high contrast with their surroundings. I also observed that it was very common for RFID to be visualised by using symbols borrowed from other technology. For instance RFID door locks often used symbols of keys (see Figure 31), and in many cases designers would use a symbol commonly used to represent WiFi to show an RFID interface. Designers also commonly represented the gestures involved in RFID interaction: symbols for a 'swipe' or a 'tap', involving abstracted human hands as

very clear instructional design for use of an RFID system. Alongside these analyses of actual interfaces, the advertising for these systems (as shown in Figure 10) also highlighted the commercial perspectives on the technology, such as the drive for efficiency and control.

These investigations uncovered the work of cultural reproduction and remediation in RFID interfaces. How did designers interpret RFID, how did they attempt to visualise its invisible qualities, what signs and iconography did they re-use from other kinds of visual design or other kinds of technology? The research at this stage built a body of knowledge about the representations and interpretations of RFID before we did any design work with the technology.

Collaborative visual research through social media

These processes of visual research were extended beyond my own research, and beyond the Touch project through social media. This began as a way to store and archive my own images using the social photo-sharing website Flickr. Flickr offers a very simple method of organising and sharing images through free-form tags: words or phrases through which you could describe and classify your images, and see them in relation to others who have used the same 'tag'. During this research I regularly uploaded images to Flickr for my own purposes, but also as a way of communicating to my design colleagues and peers about my research and interests (see Figure 32). The use of Flickr as a means of collecting and sharing visual research in this study reflects the

> role of digital images in shared, mediated meaning making in knowledge building that gives such 'archiving' a dynamic and dialogical life. (Morrison et al. in press:np)

In this way Flickr was not merely a tool for documentation and archiving, but a dynamic means of enacting a discursive activity in the design process. It built new kinds of shared meanings about RFID for a wide group of interested technologists, researchers and designers.

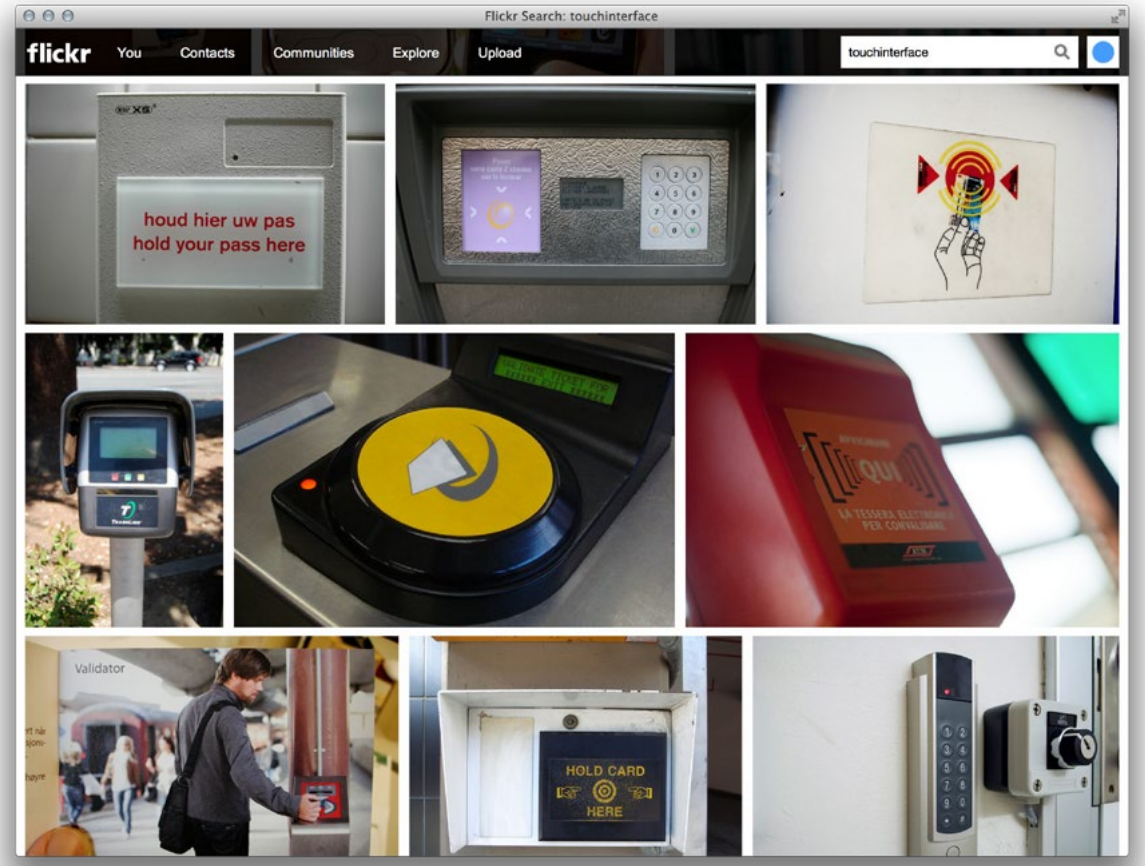

Figure 32: My shared, online Flickr archive of pictures of RFID interfaces.

I consistently used the tag 'touch interface' on all of these images of RFID interfaces, which was initially a means to search my archive, to find images for presentations and research. The structure of Flickr's interface meant that others could also contribute to this tag, and extend the research to other cities and other kinds of interfaces as in Figure 33. To encourage this, I wrote a weblog post (at www.nearfield.org) that described my intentions in documenting these interfaces and why it might be interesting, along with some examples of my research, and ended by asking others to tag their images with 'touch interface'.

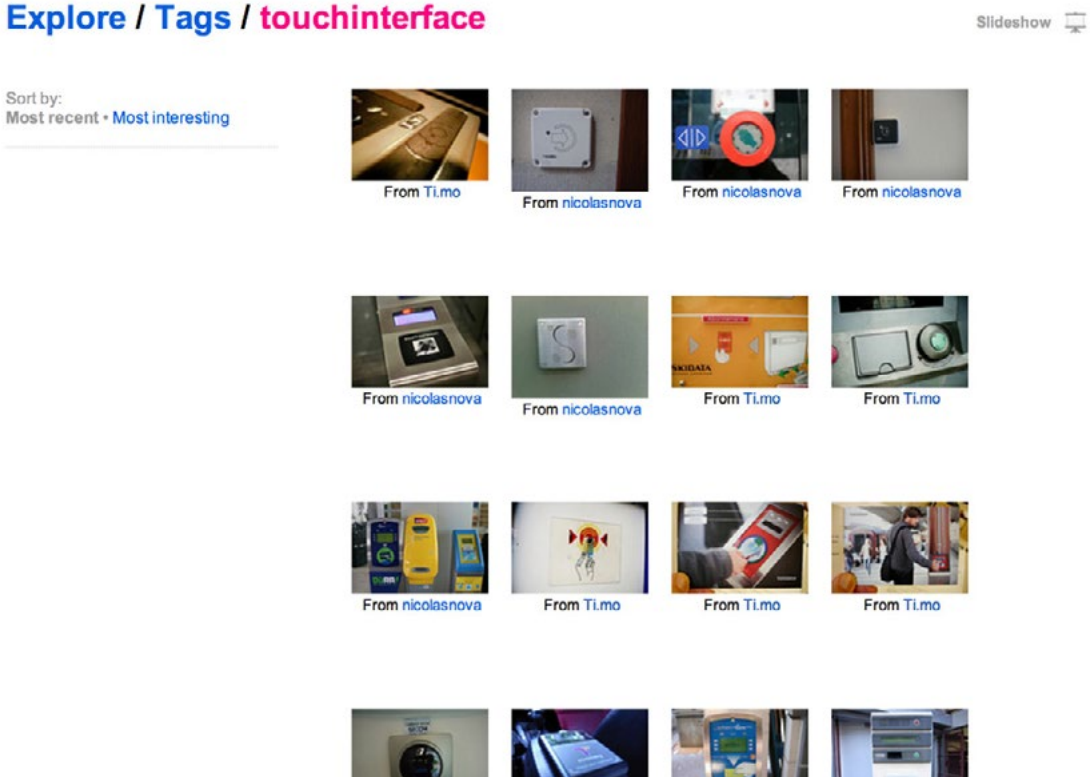

Figure 33: Flickr's 'tag' view of images tagged with the words 'touch interface', showing collected images from multiple people.

Contributions came from researchers, designers and technologists in Geneva, Paris, Los Angeles, Tokyo. My call for contributions had inspired a number of these loosely connected researchers to observe, document and reflect on RFID interfaces, shown in Figure 33 above. There were also instances of rare interfaces and strange visualisations that would have been difficult to uncover as an individual designer/researcher.

Figure 34: An example of custom RFID interface that was discovered by Nicolas Nova, a researcher outside of the Touch project who tagged his image with 'touch interface'. Image Creative Commons CC BY-NC 2.0.

This image for instance, by researcher Nicolas Nova shows a naive approach to visualising the gestural aspects of RFID interaction, that remixes other approaches such as the Oyster symbol, yet could be interpreted in many ways, such as to 'rotate' the card. Through this social, collaborative visual research, we were able to build a significant visual archive of RFID symbols, instructions and visualisations. If the work of technocultural innovation involves the practices of technocultural reproduction, then this was the investigation of the visual meanings and mediations to be taken up in this practice. It "allowed us to see an epistemic artifact in formation and enacted via use." (Morrison et al. in press:np). Technocultural reproduction in practice involves exploration and investigation, documentation through photography, and reflection

and collaboration towards a meaningful and shared understanding of the cultural contexts of interfaces.

From visual research into visual design: remediation in action
In this process of technocultural investigation, there were constructive as well as analytical processes. Using the visual investigations developed above I began a series of visual design investigations that included sketching, symbol development, and collaborative design workshops to draw and redraw symbols for RFID. This points towards the idea that visual research is not just about analysis and documentation, but about participation, intervention and synthesis in visual language, form and representations.

The first productive explorations of these interfaces was in re-drawing existing symbols (see Figure 35). I studied the existing symbols and re-drew them using Adobe Illustrator, a process that focused attention on the minute details of their design: the quality of lines, curves, shapes, the way they represented the human hand and the density and weight of their lines and fills. Re-drawing symbols is a method of getting past their 'normalisation'. In the process of redrawing one must force oneself to really look and absorb the visually designed details. It is only through this detailed and painstaking visual design work that it is possible to see underneath the surface of the visual representation and into the ways in which the representation is visually constructed. The production of visual experiments was a response to the invisibility of RFID interfaces and was a way for us as designers to work with the mediations of RFID technology without actually getting our hands on the technology.

I arrived at this approach through the need to communicate about and discuss the ways in which RFID interfaces could be included in physical objects or architecture. There was a need to generate communicative artefacts for RFID technologies and for the activities of designing and using RFID.

Through this process I constructed detailed knowledge of design decisions that had gone into these existing representations, but also created a visual library of symbols to re-use in prototypes and sketches. These symbols served the purpose of creating a visual library of RFID icons that could be used in prototyping in our design studio. At the time, brands like Visa and London's Oyster card were talking about the use of their RFID systems as universal payment interfaces across many types of transaction. However their logos and visual languages were highly protected, and there was no way to explore how these visual systems

might be applied to new interfaces without going through extensive industrial agreements and negotiations. So in our case, for low-tech prototyping and speculative design the only choice was to study and redraw these symbols ourselves.

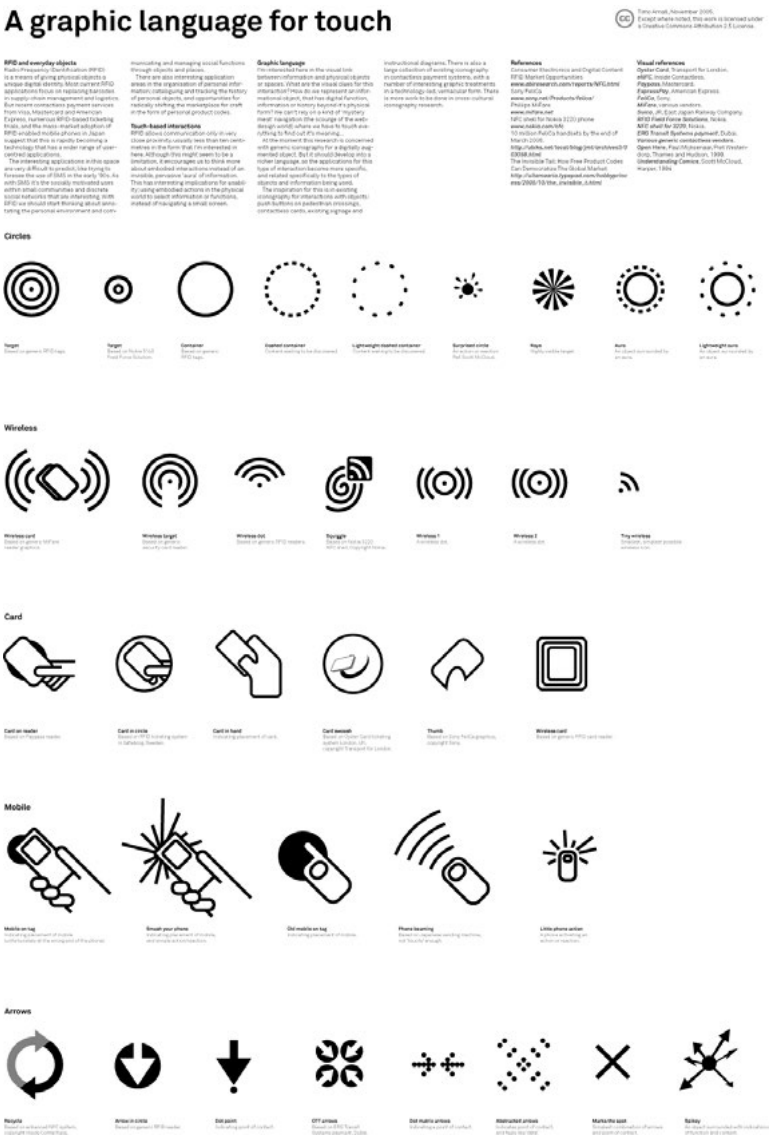

Figure 35: A visual study of RFID symbols, including remixes of existing symbols, and inventions of new languages for RFID, such as the dashed line (top, centre).

These redrawings led to concepts and directions for sketching other kinds of symbols and icons. Ideas were explored and tested through visual design. Inspiration was taken from Mijksenaar and Westendorp's (1999) provocative compilation of existing instructional design. I experimented with representing the invisibility of RFID through visual language of the dashed line, which has traditionally been used to show hidden geometry and lines in technical drawing, to show boundaries or borders in cartography, or to represent movement in instructional design. I also explored representations of movement and gesture through cartoon representations that drew inspiration from McCloud (1993). These visual representations of movement, time and action use features such as speed lines, that emanate from the direction of travel of an object, or dynamic 'sweat droplets' that represent surprise.

Figure 36: A full collection of propositional, speculative icons for RFID hanging in our design studio.

They were used to represent RFID interfaces on prototyped products, lending realism to our work, and arguing for the consideration and placement of RFID interfaces. In teaching we used the icons to explain RFID (see figure 36), and also ran workshops to further develop visual approaches.

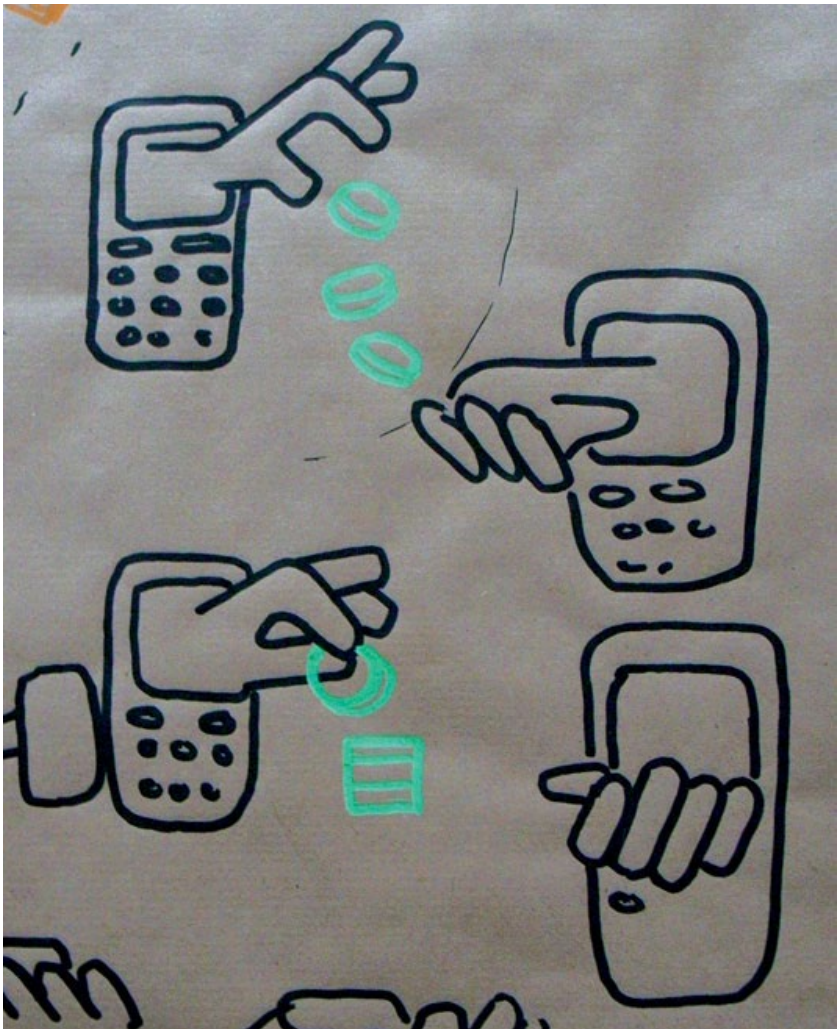

Figure 37: detail of design sketches exploring the concept of financial transactions with mobile phones.

This process of developing RFID symbols led to the creation of a workshop between the project partners AHO, BERG and Central St Martins School of Art and Design in London, UK. The aim of this workshop was to push the conceptual and aesthetic qualities of RFID icons in new directions, and to formulate some visual approaches. Importantly this workshop explored a set of symbols that did not just address the invisible quality or the gestures of RFID, but communicated the interactive potential of RFID; the transactional and systemic aspects of RFID use. In Figure 37 is a set

of sketches that attempt to convey the concept of financial transactions between two proximate mobile devices.

This is an example of creating a repertoire for early-stage conceptual design work with technology as described by Nordby (2011). Where Nordby takes the concept of repertoire and applies it to the development of RFID interaction potential, here we are creating a repertoire of visual language, symbols that can be used as a means of thinking about and developing the meanings, representations and understandings of RFID technology.

Analytically these visual investigations also show that rather than representing a proximate future of seamless interaction with invisible and unobtrusive interfaces, RFID is already established as a visual feature in daily, lived experience in many cities and cultures. This visual research clearly represents the shift identified by Bell and Dourish (2007), away from investigating proximate futures in ubiquitous computing research to investigating technologies that are already in use and already meaningful. In designing new symbols it moves towards how those meanings can be changed and shaped.

To uncover and explore the meanings and representations in these emerging technologies it is necessary to conduct investigations that mix technology, design and methods from the social sciences. In their work towards a manifesto for methodological experimentation Mainsah and Morrison (2013) find that design has many possibilities for experimental and hybrid enquiry that can be built together with qualitative enquiry from the social sciences. They refer to a study carried out by Andrew Barry, Georgina Born and Gisa Weszkalnys (2008) that is summarised by Lucy Kimbell (2008) where she proposes ways in which qualitative inquiry, particularly ethnography might connect to practices of design:

> Rather than just making research more visible and better understood, design synthesizes it in the creation of visual artefacts that suggest new ways of doing things, new products and new services. (Mainsah & Morrison 2013:156)

They relate to the modes of experimentation in design and the social sciences as described by Wakeford (2003) in "the use of visual practices and design sessions as ways of doing cultural studies of technology." (Mainsah & Morrison 2013:157). Here there is a practice that sits between ethnography and design, where the product of design, social and cultural

studies of technology are more than just texts, but sketches and other visual output.

In this practice of exploring, documenting, drawing, re-drawing and building visual languages I have shown how design can play a part of an approach to meaningfully interpreting a technology like RFID. By taking up the ideas of remediation and technocultural reproduction in interaction design practice, we are able to more fully account for the process of visual research and development as an approach to understanding and developing the meanings of an emerging technology like RFID.

Approaching and exploring design materials

As recounted in the opening anecdote in Chapter 1, the design practice and research in the Touch project focused on design materials and material exploration as a central issue. This emerged from a realisation that there was a need for greater understanding of RFID as a design material.

Early product prototyping and critical design activities
The approach to materials can be traced back to the prototyping stages of the Touch project, where we created products and services using RFID technology. It was the problematic issues in these prototypes that led us to a design material approach to RFID. Two examples of these prototypes include *Skål* and *Sniff*.

Skål was a wooden bowl, shown in Figure 38, that when connected to a television would allow for the control of media through the use of physical objects. It used an RFID reader in the base of the bowl to detect RFID tags embedded inside smaller physical objects such as wooden blocks, toy figures and fabric animals. It was specifically designed for a more playful use of media, and in doing so, advocated for new kinds of media consumption that might be an interesting way for children to interact with media in less passive ways.

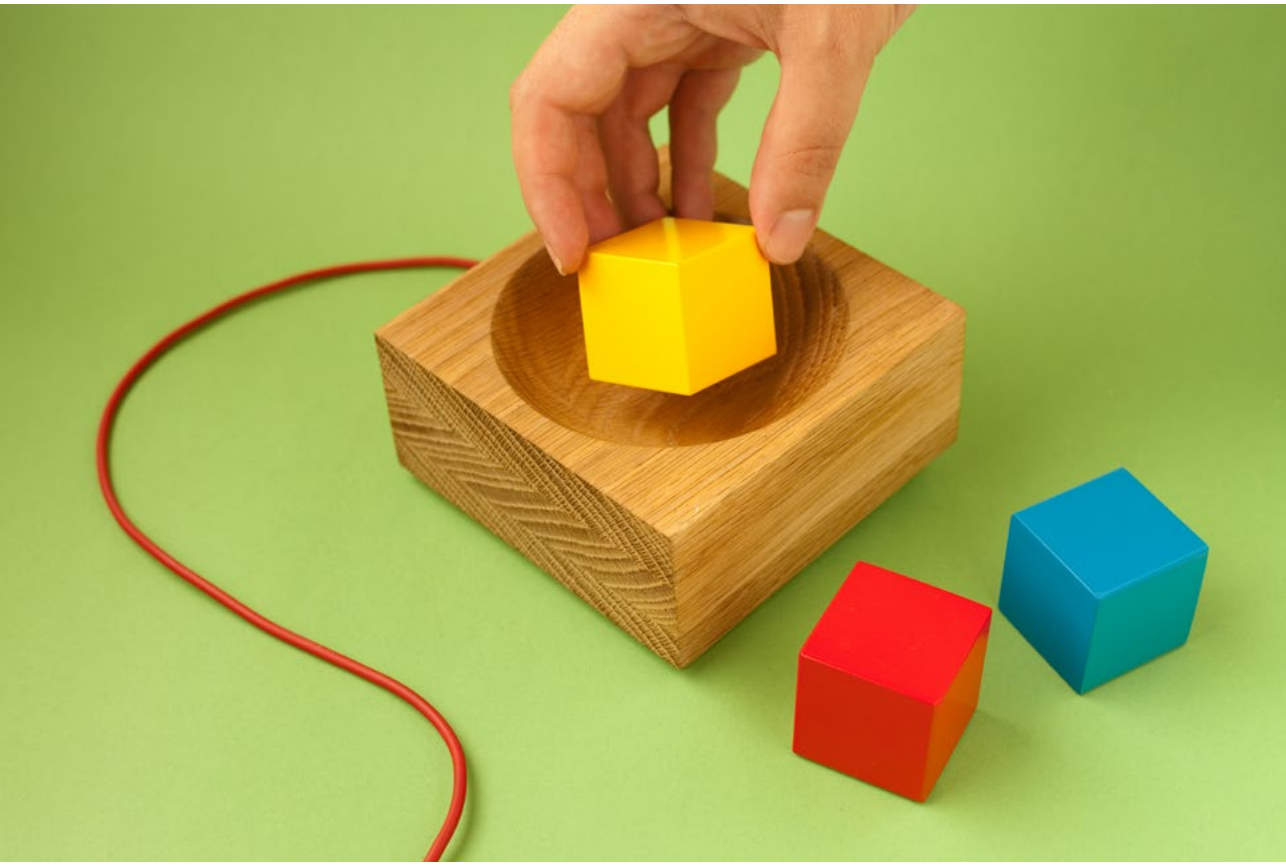

Figure 38: A still from the film *Skål*: https://vimeo.com/6698128

By prototyping the product to this high degree of finish, we were able to test it out in context, at people's homes for long periods of time, refining the form, interaction and content. Although object-based media was not an original concept, having been explored extensively before at MIT (e.g. Ullmer & Ishii 1999, Zigelbaum et al. 2007) Microsoft (Pinhanez et al. 2000) and elsewhere (e.g. van den Hoven & Eggen 2004), *Skål* instead took a product design-led approach. By this I mean we created a physical form, used materials and designed interactions that we felt were viable as a piece of consumer electronics, sitting alongside Apple, Sony, Bose, etc. devices. We also tested the interaction extensively in real people's homes, with real televisions and content, in and around everyday life.

Figure 39: A still from the film *SnifF*: https://vimeo.com/6602990

Sniff was an interactive toy dog, shown in Figure 39, that had an RFID reader in its nose that detected RFID tags embedded in other objects or in the world. When *Sniff* detected various objects it would respond through sound and vibration, not through visual or screen-based feedback. In this way it was initially designed for children with visual impairment but it was also designed as a universal toy that could be appreciated across children of different abilities and ages. Like *Skål*, *Sniff* was prototyped to a high-level in order to test it out in everyday situations and to survive the rough and tumble of real children's activities. The film above shows the prototype in action.

These prototypes could be seen as part of a 'critical design' tradition in the way that they critiqued the dominant visions of RFID technology by offering up alternative views on the technology. They countered

the ubiquity and utility of the technology by showing it as a playful, situated and self-contained feature of highly aestheticised objects. They challenged the notion that RFID was inherently a tool of 'control society' by creating ways in which it worked as a private, self-contained, personal and domestic technology. In this sense they are both artefacts of mediation and mediating artefacts, they both mediate new kinds of meaningful interaction through their use, and create new meanings through their form, aesthetics and media representations.

Each prototype was communicated through a film, and they represent a mediational approach to interaction design, but what is significant here is the way that they shifted our own perspectives from prototypes and a 'critical design' approach, towards a more material centric approach. They demonstrated to us our lack of knowledge about RFID technology, particularly its physical and spatial phenomena.

Early design material exploration

To create *Sniff* and *Skål* we needed to generate a significant amount of technical knowledge about RFID as an interface technology. First, we needed to source electronic components, to research the technical platforms and standards, and to test and probe RFID hardware, on order to understand how to build interactive interfaces with the technology.

RFID is not as simple as its interactive surface suggests, it functions through quite complex electromagnetic induction. In an RFID tag there is typically a coil or a pattern of wire that modifies (modulates) a received magnetic field generated by an RFID reader. In this modulation it transfers a digital identification number which is picked up by the reader. The effectiveness of this electromagnetic interaction is defined by many things, including the design of the antennae, the surrounding environment, the hardware and software used to analyse and interpret the signals, and the frequency of the radio waves. By changing these things we can have an RFID system that works over a distance of a few centimetres or one that works over a few kilometres. Some of these interactions will easily pass through metal or water, and some will not.

If this physical complexity were not enough, the development of RFID standards has occurred in many diverse ways. This means that there are many different competing standards and protocols with different affordances and qualities that must be investigated and understood in order to be able to make reasoned and sensible decisions about how to implement them in a prototype interface. The most common forms of RFID, the ones we investigate in this research: 'low-frequency' and

'high-frequency' operate at a distance of a few centimetres and can be highly sensitive to the kinds of materials and environments that they are embedded within. But even these RFID systems lack documentation and certainly any kind of existing framing as a design material.

Once they have been discovered and selected most electronic components are supplied with a data-sheet, a technical document that summarises a components functions, capabilities, interfaces and limitations. But these data-sheets are mostly based on highly specific and contingent engineering knowledge. In the case of RFID, one of the key pieces of information contained in data-sheets is the range of the RFID reader: as interaction designers we would like to know whether a travel card will be read by bringing the card within 5cm of a reader, or whether it would work from 50cm away; this would change the design of our 'getting on and off the bus' interaction considerably. Unfortunately, the information in data-sheets often seems to be based on theoretical limits, so an RFID system that in practice that reads only 2cm might be listed at 10 or even 20cm. Approaching order of magnitude differences in this critical material quality. So, not only are data-sheets an obscure and difficult form or material knowledge to understand and interpret, the 'data' they contain is based on assumptions that are perhaps acceptable in technical domains, but give interaction designers very little handle on the technology as a usable 'material'.

This was especially problematic in teaching situations where we encountered multiple issues of students not having a deep enough material knowledge to be able to reconcile the thinkable with the possible. In many cases when we presented low or high-frequency RFID as a material for design students to work with, the initial concepts that came back were about being able to track 'every object in this room' or being able to 'see' all of the objects in a bag. To engineers or technology experts, these scenarios are clearly outside of the material capabilities of these most common kinds of RFID systems. The problems arise from a conflation of different kinds of technology, perhaps drawing on experiences with other kinds of long-range, powered RFID systems, or with Bluetooth and Wifi.

Traditionally, in engineering and technical domains, issues of understanding the material qualities of electronic components may not have been such an issue. The shared meanings, norms, and 'object world' understandings in such domains meant that there was much less need to think about the mediation or communication of technical work to be understood by other communities or in other practices. But

recently there has been significant development in open software and hardware platforms that are designed for use by interaction designers in prototyping situations. Platforms such as Processing and Arduino are exemplary in the way they develop open and shareable learning tools, with examples, codes, libraries and discussion forums that are accessible to less technically literate audiences. There is then a need to account for the understanding and communication of hardware and software as design materials across multiple domains, including engineering, design, art and communication design.

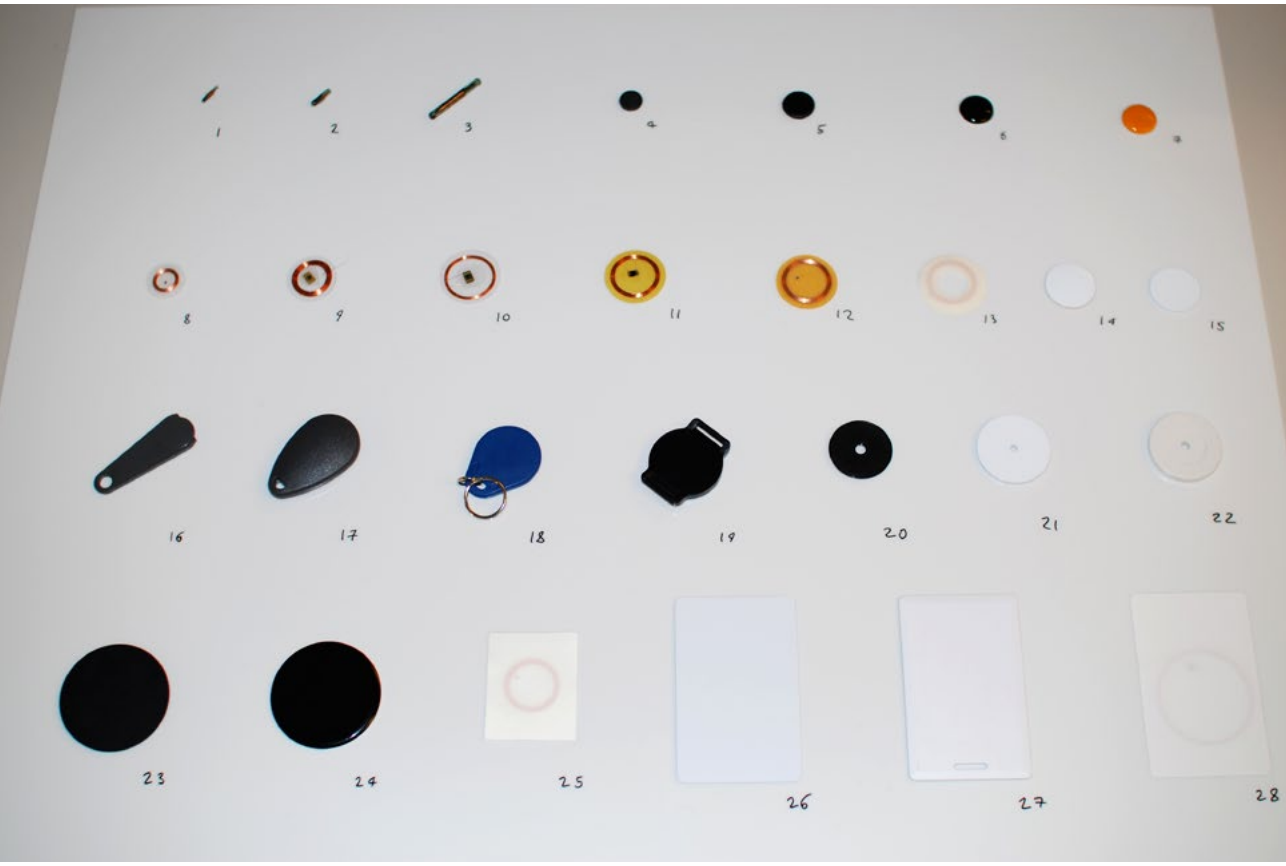

Figure 40: A collection of RFID tags glued to white acrylic, as a 'demonstrator' used in teaching masters interaction design courses.

So in the design of *Skål* and *Sniff* we had to source our components and do extensive technical testing, just to find out how the RFID systems behaved in practice. We developed a tacit knowledge of the way that a

particular RFID reader would interact with a particular tag. We sourced as many RFID tags as we could and catalogued them (Figure 40), using hot-glue to fix them to a board where we could test and refer to them for our own practice and in our teaching. We related this growing body of knowledge to our students in our masters courses. We discovered that some combinations of tags and readers simply failed to work, the tiniest of glass tags for instance had such short read-ranges that they would not communicate to a reader through the nose of *Sniff*, or through the thick layer of wood in *Skål*.

Figure 41: A wooden stick with a tiny embedded RFID underneath the red painted end.

In other cases we found new material opportunities from the constraints in this relationship: a small RFID tag used in *Skål* would only read if it was placed in one exact spot, so we embedded it in a stick (Figure 41, above) and asked our users to 'stir' the stick inside the bowl until it hit

that spot. See article 4 (Martinussen & Arnall 2010) for more details on these experiments. This was an emergent interaction form that was only possible through understanding and exploration of the radio fields and interactions between reader and tag.

Developing a design material approach

Why are the materials and phenomena of ubiquitous technologies like RFID so important? Partly this stems from a desire to continue a Scandinavian tradition of honesty in form, function and material deriving from such sources as Acceptera (Asplund 1931), the development of modernist approaches that culminated in the high-modernist buildings that expressed honesty of material and in self-evident products. It also stems from a recognition that culture and technology are intricately intertwined, and that user-centred or participatory design approaches pursued at the expense of technical knowledge, while also essential processes, are not enough to fully account for invention and innovation in design.

How do we as designers account for this development of design material knowledge of RFID? As we saw earlier, approaches to material in interaction design have focused on software and have not yet managed to fully account for treating emerging technologies like sensors and physical interaction. Even early on in computing history material played a large role in the development of interaction. In his infamous quote, the influential computer scientist Alan Kay said in 1982 that "people who are really serious about software should make their own hardware" (Hertzfeld 1982). In this he implies that in order to make good software one must have a deeper contextual understanding of how that code runs, in other words a material understanding of computation.

In her account of critical interaction design research Ramia Mazé (2007) finds that interaction design must look more closely at its design traditions such as the 'artist-designer' and 'engineer-designer' without falling into nostalgic notions of 'craft' or purely instrumental notions of technology, where she suggests that "post-industrial technologies must be materialized so that computational and interactive possibilities may be perceived and acted upon." (ibid:269). She further claims that

> a common supposition in moving to a more technology-oriented practice is the impoverishment of material traditions. The increasing complexity and industrialization of design has meant that technical specification and formal representation have

> taken precedence over direct and hands-on relations to materials. (ibid:260)

However, as Mazé also points out, it may be difficult to treat computation as material; the complexity, scale, shape of a computational system may not reflect what it does or how it works. Mazé also cautions against treating material form as symbolic or representational in product design:

> the application of additional 'product languages' to surfaces and interfaces is problematic with the miniaturization of form factors and shrinking 'screen real estate'. Just as we can no longer judge by appearances, perhaps we can no longer merely design surfaces. (ibid:267)

There are aspects of new and emergent digital materials that can very easily be treated as design materials. When looked at more broadly than just the underlying software or behaviour, they are not 'materials without qualities' as suggested by Löwgren and Stolterman (2004) but a set of phenomena and systems that can be explored, understood and shaped.

'Material exploration' is a term coined by BERG as part of the Touch project to describe a material-based approach to invention. Tom Armitage, a creative technologist at BERG, accounts for the practice of exploring digital data as design material:

> Invention comes from design, and until the data's been exposed to designers in a way that they can explore it, and manipulate it, and come to an understanding of what design is made possible by the data, there essentially is no product. To invent a product, we need to design, and to design, we need to explore the material. It's as simple as that. (Armitage 2009)

Material exploration highlights the importance of design materials in interaction design. Material exploration builds upon design's strong history and practice of working with and understanding material as one of the central constraints of what is 'thinkable'. Returning to Manzini's reflections on the 'Materials of invention' we find that even in 1989 he had some thoughts about digital materials and what this might entail for design material practice:

> Today, a designer who intends to work in the field of possibilities made available by technical innovation not only must find an

> orientation among numerous options, but must especially adapt his intuitive capacity, creativity, and work method to the general trend towards abstraction, immateriality, and multiplicity of the parameters with which he must deal in order to work with matter. [...] This hybrid knowledge typifies the image of the modern designer [...] An abstract and theoretical knowledge of materials is no longer just one of the possible approaches, but the only feasible approach. (Manzini & Cau 1989:53)

I suggest here that the approach to abstract and 'immaterial' design materials is through hands-on processes of material exploration that build knowledge of materials in interaction design. As I outline in Article 1 (Arnall 2013 in press), this process involves the kinds of technical investigations detailed here, and then mediation of this knowledge in order to share and collaborate around these understandings.

In addition to the theme of material exploration developed in the Touch project, we also developed the concept of 'Immaterials'. This was an invention in language, that helped us to frame these emerging materials and our approach to them. Team member and designer Matt Jones forced a plural form of 'immaterial', implying not just a single immaterial phenomena, but a generalisable concept of immaterials in design (Jones 2009) that I describe in Article 1 (Arnall 2013 in press). The term provocatively emphasised the importance of the immaterial in interaction design and as we shall see, the term became very important in communicating the resulting work.

A hands-on approach to technological materials is of critical importance to the mediational materials approach taken up in this thesis. Mazé suggests hands-on approaches to both traditional and technological materials in interaction design. I'd further argue that we need to develop specific approaches to the material forms of interaction design, particularly in the emerging areas of tangible and sensor-driven interaction, as Fernaeus and Sundström (2012) note, where materiality and physicality are once again primary material qualities. I'd argue that these approaches include rather than exclude the symbolic and representational as well as the physical, that we must develop methodologies, techniques and languages for the representing and mediating the qualities of technological materials.

Exploring RFID as a design material

As outlined in the opening anecdote of this thesis, the first time I recognised the possibilities of seeing the radio field of an RFID system as

a material was during an early workshop where we developed the RFID pen.

Figure 42: A still from the film *Touch: Design practice & experiments in film*: https://vimeo.com/8042711

In Figure 42 above you see some early documentation of the RFID pen in action, and the way in which it draws out the spatial relationships between an RFID tag and an RFID reader. The visual material it produced, in the form of pen and ink sketches, were wonderful material artefacts. As cross-sections through an RFID-induced interaction, they were evidence of an actual spatial, physical, interactional material produced by an invisible and complex technical system.

Figure 43: An early, hand drawn cross-section through an RFID field using the RFID pen.

It was these early experiments, such as the expressive, yet technically constrained, mappings of RFID interaction in Figure 43, above, that challenged us to think about the role of interaction design research in creating and sharing design material knowledge. Material exploration as a methodology and approach addresses the issues raised by Fernaeus and Sundström (2012) detailed in Chapter 2 of how to understand and explore technical materials. What about the other two questions, how do we communicate material properties, and how might this knowledge be used as a resource in interaction design? In the subsequent months we conceptualised and developed this approach, and tested out a number of directions through which we might develop further, more advanced and expressive visualisations of the material phenomena of RFID systems.

Mediation and communication of RFID

Design practice and research has close relationships to photography and filmmaking, where, for instance, Raijmakers (2007) sees documentary filmmaking as an addition to the multidisciplinary mix in design, that can inform and inspire design processes. However, visual tools such as photography and video are most often seen in design research as an aid for documentation of ethnographic or participatory processes (e.g. Wakeford 2003), rather than a means of creative, constructive means of design production. In this section I explore how photography and filmmaking are a generative, constructive practice, a space in which design research can invent, reflect and communicate. I describe the approaches and techniques that we used to mediate and communicate about the materiality of RFID. In order to do this, I'll first describe some of the history of photographic and filmic techniques that have been central to my practice as a creative designer.

Photography and filmmaking as design practice

As we saw earlier in the documentation of RFID interfaces, photography has been a central component of my design practice. Photographic techniques have been used in multiple ways throughout the project, to research existing interfaces, to illustrate cultural context, to record process, to capture workshops and meetings, to represent prototypes and products, and as we shall see, to creatively explore materials. Photography is an adaptable medium, it works for representational documentation and 'evidence' as well as for more creative, ambiguous and expressive uses. By using photography we can allude to the history of advertising, make connections between our work and famous street or architectural photographers, and by addressing the nuances of product photography, we can creatively situate our prototypes alongside products from Apple or IKEA.

Figure 44: On the photography and filmmaking set of Immaterials: Ghost in the field. A dark room with a 'stage' set for photography of RFID readers and tags.

Film and animation has also been a central part of my practice. Trained as a filmmaker I have decades of experience in creating moving images, in animation techniques and in editing footage into narrative or documentary forms. As a designer I see historical films such as the Eames' 'SX-70' film for Polaroid as one of the high points in the communication of technology. In the first of four films made for Polaroid (Kirkham 1998:357), the Eames' explain a completely new technology of instant photography to a mass-audience. The SX-70 camera was revolutionary from many perspectives, it used new optical and mechanical inventions, it used new chemical processes and it embedded new kinds of behaviour and processes controlled by early microprocessors and light sensors. The SX-70 film is 10 minutes 52 seconds long and starts with a quote from photographic history, followed

by images showing the use of photography as a cultural phenomena. It then proceeds to show how the SX-70 changes this cultural activity by showing how it works: it explains the optics, the chemical processes, and the systemic, digital functions of the camera's behaviour, all adding up to an instant photography experience. It finishes by showing how the camera might be used in everyday life, and projecting what this might mean for photography in general. This work shows the expressive and explanatory power of filmmaking in design, how it can relate the everyday to the cultural, then explain microscopic technical and chemical processes and relate it back to human scale. The SX-70 film represents a key reference point in our thinking about how photographic, animation and film techniques can be used to explore and explain emerging technologies.

More recently, in architecture, Hogben (2000:219) finds that digital video's

> capacity to work with synthesised and captured images, that can be modelled and reverse engineered, offers a powerful mode of exploration, iterative development and communication for information-rich projects that depend on a complex mobilisation of team skills and technical resources.

By bringing these communicative approaches from photography and film into our design process alongside the technical material investigations, we began to see opportunities for expressive and communicative, even spectacular, mediational material approaches. Reflecting on our enthusiasm for the scrawls and scribbles of early RFID Pen drawings, we wanted to further explore the methods for showing the spatial aspects of RFID interactions.

Developing photographic and animated approaches to RFID

Light-painting is a creative image-making technique familiar to many artists, filmmakers and designers. It is a fundamentally photographic technique, where a long exposure image is taken in a dark room (like Figure 44) and a light is moved through the image. These 'paintings' have been explored by many artists and photographers including Étienne-Jules Marey, Man Ray, Picasso, Jack Delano, Andreas Feininger and Eric Staller. In 1914 Frank and Lillian Gilbreth used light-painting techniques to study and improve the practices of bricklayers and factory-line workers, photographing their movements with lightbulbs attached to their hands (Price 1989).

Having experimented with this photographic technique in the past, we knew that it was an interesting way of situating intangible or temporal phenomena such as movement into the photographic context in which it occurs. Light painting is a technique that can capture both a movement and the space in which it happens.

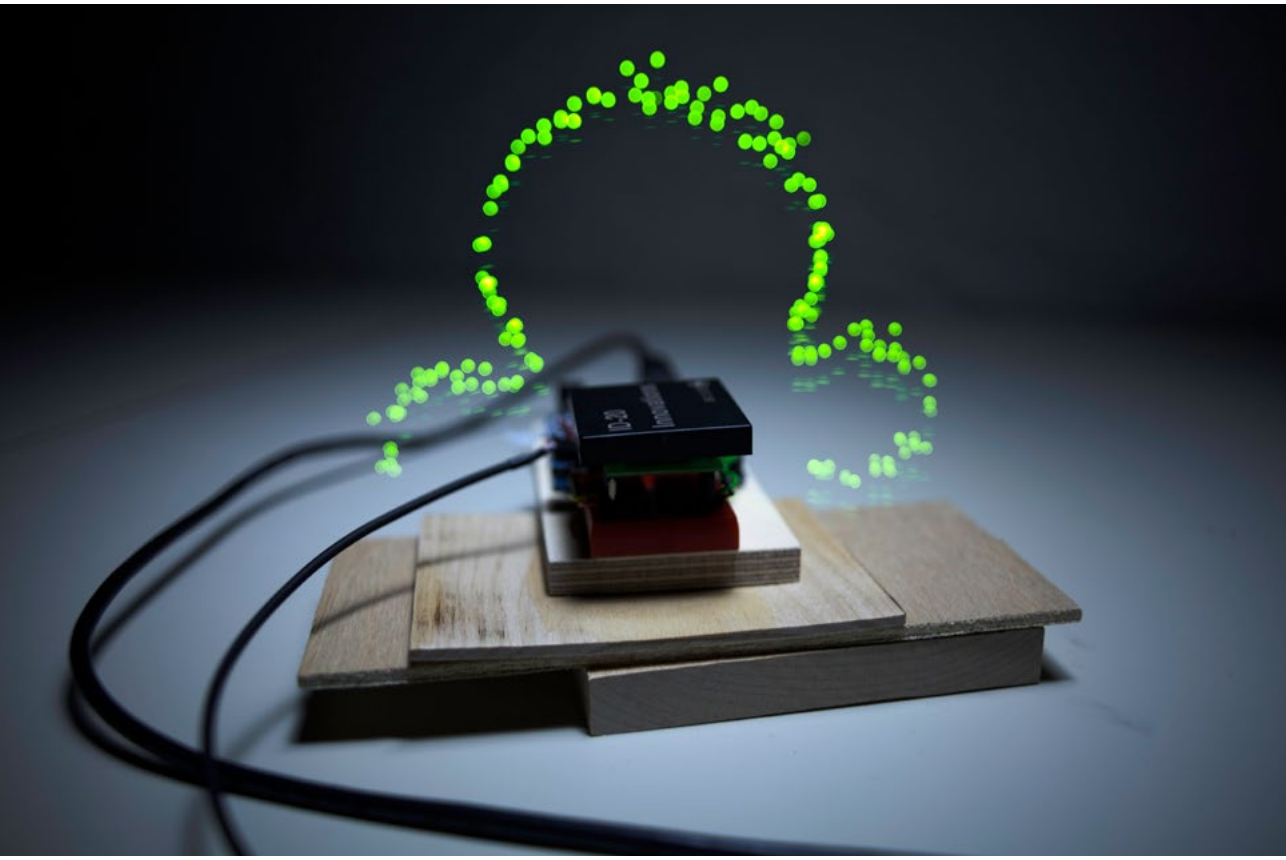

Figure 45: A still from the film *Immaterials: Ghost in the Field*: https://vimeo.com/7022707

In Figure 45 above we articulate our technical knowledge of RFID through a light-painting technique, we developed a process where we could photograph the spatial, physical characteristics of an RFID system. We developed a probe with an LED attached to an RFID tag, that would flash every time an RFID reader sensed it. By carefully moving this reader while taking a long-exposure photograph we could paint an outline of the 'readable volume' of the system.

As the film explains, this is in order to give us better knowledge of how RFID inhabits physical space, and to enable us to see RFID as a physical material that we can use alongside the other materials we might use in design, such as wood, fabric and plastic. The film both explains and shows a means of mapping a phenomena in physical space, much like making a scale drawing with callipers or using a theodolite to survey a space. Extruding light into the space depicted in a photograph is a powerful representational means of creating new expressions that are intimately bound into all its inherent physicality, with shadows, reflections and radiosity of the photographed physical world. The film has a scientific, evidential quality to it, in that it visualises actual interactions in an RFID system, in a way that is hard to do through simulation or theory. It relied heavily on a technical understanding of RFID technology that was drawn from studies in HCI, in technical literature as well as our own technical explorations based on data-sheets and specifications, described above. In order to create this technical setup for light painting in Figure 44 we again relied upon a set of technical materials developed by open source software and hardware communities, Processing and Arduino respectively.

Figure 46: On the photography and filmmaking set of *Immaterials: Ghost in the field*. Team member Jack Schulze solving production problems.

The filmmaking involved in this work (seen in Figure 46) relied on a knowledge of the materials of film, visual effects and animation: layering images through various image modes, compositing, frame rates and manipulations of time. Also of the genres of film itself, how a documentary film sets up a context and a question through visual means, and explicates this question through visual and spoken examples. This was an extraordinarily complex and obscure process to attempt to make meaningful for a broad audience. In order to do this, the film contained a series of short segments, one that set the contexts through showing RFID in the world, one short but critical sequence that explained the light painting technique, a longer sequence that unravelled the complexities of the mapping, and a conclusion that wrapped up the findings into a visual symbol. As with the Eames' SX-70, film as a medium functions

as a flexible and coherent means for organising these various meanings within a cultural frame of reference.

This film shows the mediational approaches that help us make things apparent through techniques such as animation, light painting, time-lapse, and the use of film genres. The visual techniques are also a material resource for design, the design materials here are at once technical, cultural and visual, an example of visual-technical social-semiotics. This filmmaking practice is also the process through which knowledge is gained from design practice. The visual processes, symbol design, photography, animation and light painting generate knowledge both through tacit design activities, through their documentation as photographic images and through the resulting visual evidence in media.

Mediation across media

The film, titled *Immaterials: Ghost in the field* was uploaded to the video sharing website Vimeo. There it was viewable online in high-definition, with the options of sharing via social media and embedding in other websites. The film was written up as a weblog post on the Touch weblog where the film was embedded and described. It was contextualised in a way that explained the need for exploring the opportunities and constraints of invisible technologies, some of the problems with invisibility, and an explanation of the process.

Figure 47: *Immaterials: Ghost in the field* film featured in German design magazine 'Weave'.

At the time of writing the film has been seen by almost 200,000 people on Vimeo and still achieves around 400 plays every week. It was embedded across design, news and technology websites such as *The Guardian*, *Wired*, *Le Monde*, *Popular Science*, *Slashdot*, *Gizmodo* and many other magazines (see Figure 47). It was also shared and written up from many perspectives across hundreds, if not thousands of weblogs, Facebook and Twitter posts, by people from as diverse backgrounds as educational design, radio engineering and including science-fiction authors, RFID marketers, RFID privacy experts and advertising journalists. The discussion that it catalysed centred around RFID as a material phenomena and as a design material, a discourse that was largely non-existent before we made the film. The film also crossed between communities of practice by being used as an engineering teaching tool at the Open University, featured as part of popular media including the BBC and the Discovery Channel, to

exhibitions in art contexts and popular design culture at MoMA in New York. Creating a cultural expression that is able to cross these boundaries is only possible through the combination of many skills, people and disciplines. This 'cultural invention' combines technical exploration, aesthetic invention and documentary media in a way that makes a misunderstood and obscure technology legible. This is discussed further in Article 1 (Arnall 2013 in press).

Remediating film genres to communicate RFID

The next film is an example of us as designers explicitly remediating cultural references and material back into the creation and invention of a film intended to propose alternative perspectives on interface technology.

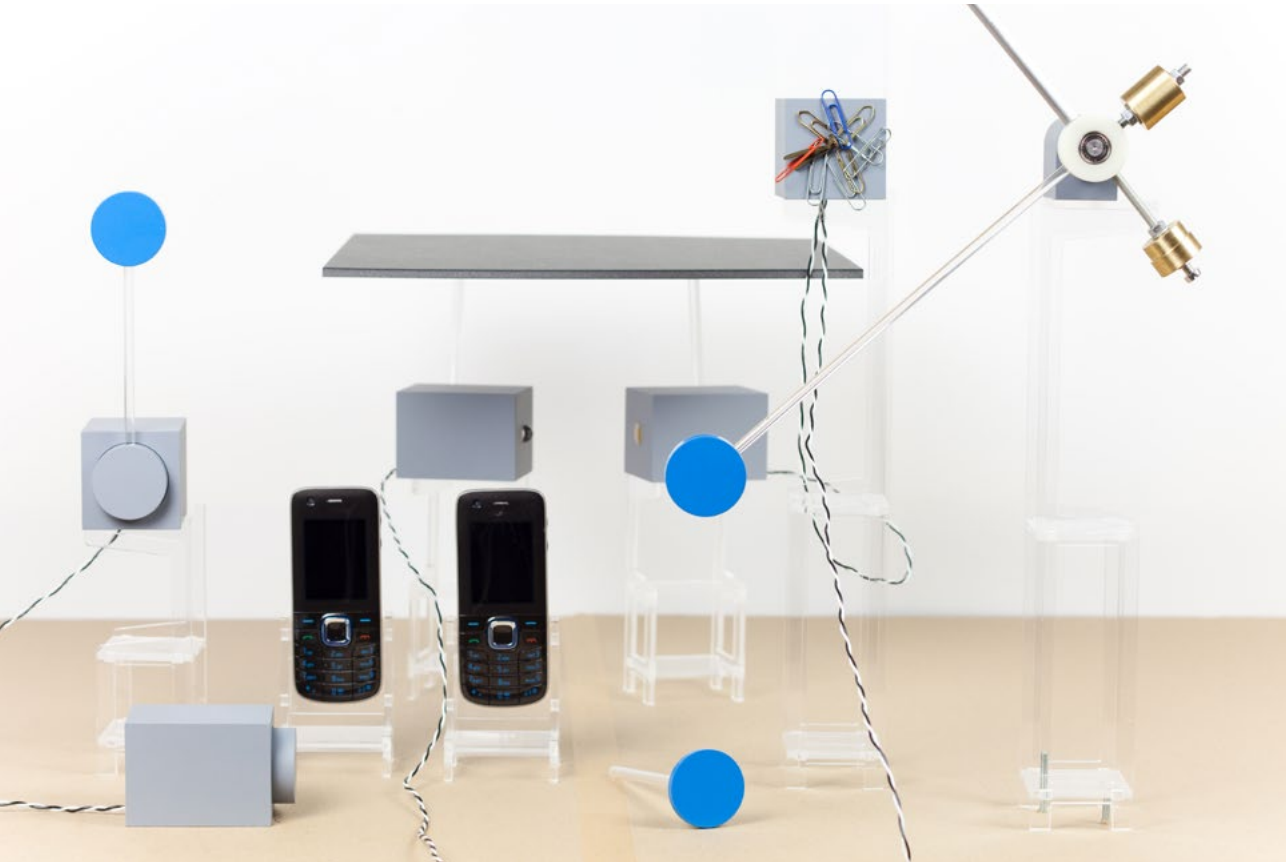

Figure 48: A still from the film *Nearness*: https://vimeo.com/6588461

Nearness (shown in Figure 48) is a short exploration of technology that enables 'action at a distance'; short range radio, text messaging, light sensors and magnetism. This 'action at a distance'—things that affect each other without touch—was taken up as an idea to address the central material characteristic of RFID, and the increasing amount of technology we interact with everyday that operates in this way, whether it is an RFID travel card, a mobile phone or an automatic door.

However, in this film we did not explain the technology, its use or implications, or talk about affordances or specific design materials. Instead we drew upon an existing genre of filmmaking, the 'chain reaction' made famous by Fischli and Weiss, and popularised by Japanese TV and a notorious commercial for Honda. We also drew upon the tradition of the useless machine, such as Bruno Munari (2008) and such inventor/illustrators as Heath Robinson and Rube Goldberg. Instead of creating a prototype interface or product, we worked with a model-maker to create a set of abstracted 'interface blocks', smooth grey blocks supported on acrylic stands, each with an embedded sensor or actuator, that all related to and affected each other. The blocks were set up in series, and a chain reaction was initiated by touching an RFID block with a London Transport Oyster card. The resulting chain reaction that lasted for just over a minute, where nothing touches, was filmed with only one cut.

The film then was the main 'design object', with photographs and descriptive text playing a secondary yet important role in the online mediation of this work. It is perhaps the strongest case study in this thesis for a communicative sensibility in design research. The importance here is in the potential for transformation, the ability to offer, show, and make change. To be able to share this film, to give access and open up new perspectives. The film represents us as designers being located in our cultural context, not just creating material for our own knowledge, or for a design community. But about building resources for others to think, by offering evocative and open-ended resources for discussion and response.

Nearness differs from much work in critical design in that it strongly acknowledges its relation to existing popular culture; the chain reaction and useless machines. In this way its communicative aims are much clearer, it is purely about representation and participation in culture, it is open and obvious about taking up visual, narrative tropes and using them to sensitise us to the materiality of new technologies. It also differs

from critical design in way that it creates a material knowledge rather than a critical or conceptual perspectives.

This film then, explicitly represents the hidden work that many other, existing design and research works already do, they pick up on cultural tropes and themes, they use them as material alongside new materials to make new concepts clear, to propose something new, to show the possible and thinkable. In Nearness, we drew upon the history of the chain reaction film, to make a new cultural object that embedded a new material perspective on interface technologies.

Mediational material

The mediational material approaches are practical and analytical means of 'designing culture' in the process of technological innovation. Balsamo's approach takes concepts from the humanities and uses it as a means of informing the design process at "the first phase of any technological design project" (Balsamo 2011:14). She calls this a process 'hermeneutic reverse engineering' that draws together both reverse engineering; deconstructing an engineered object, and of hermeneutics, for interpreting meanings, in order to do 'cultural analysis'. While I share Balsamo's theoretical grounding and analytical aims, I do not attempt to provide instrumental means for improving innovation. Instead I want to provide perspectives and approaches in design research that open up for exploring the potential of contested emerging technologies such as RFID.

In this research we took RFID and related it to existing visual languages through making new visual media such as symbols, photography, light-painting, animation and film. We did this in order to contextualise, interpret and critique and discuss the technology. Using signs, symbols, visual techniques and processes as semiotic resources to interpret new and emerging technologies and to make them visible and legible as part of popular culture.

Discursive design is about generating these culturally-related objects that help us look at the technology and its implications. It's also about bringing the communicative, the visual, genres, forms, social media to the scholarly approach in design research. Here there is an intention to engage the popular cultural understanding. The popular technocultural imagination that is largely defined by large industries and organisations such as Microsoft and Apple who have particular visions for the future

of our use and the design of technology, or by popular media which is often outside of the realms of materially possible. Design research then has a role to play in this shaping of a more pragmatic popular cultural imagination, built on perspectives that have thorough understandings of the materiality of interface technologies.

Appropriating and extending the mediational material approach

Although the resulting films have a highly polished, finished aesthetic, the visualisations they contain have an openness that is difficult to quantify. Because they are intriguing and spectacular images, they invite others to investigate and question the techniques, and this has motivated people to modify and extend the techniques to other technologies and contexts. The visualisations have a 'capacity to unfold',

they give rise to questions. In this way they can be considered trans-epistemic.

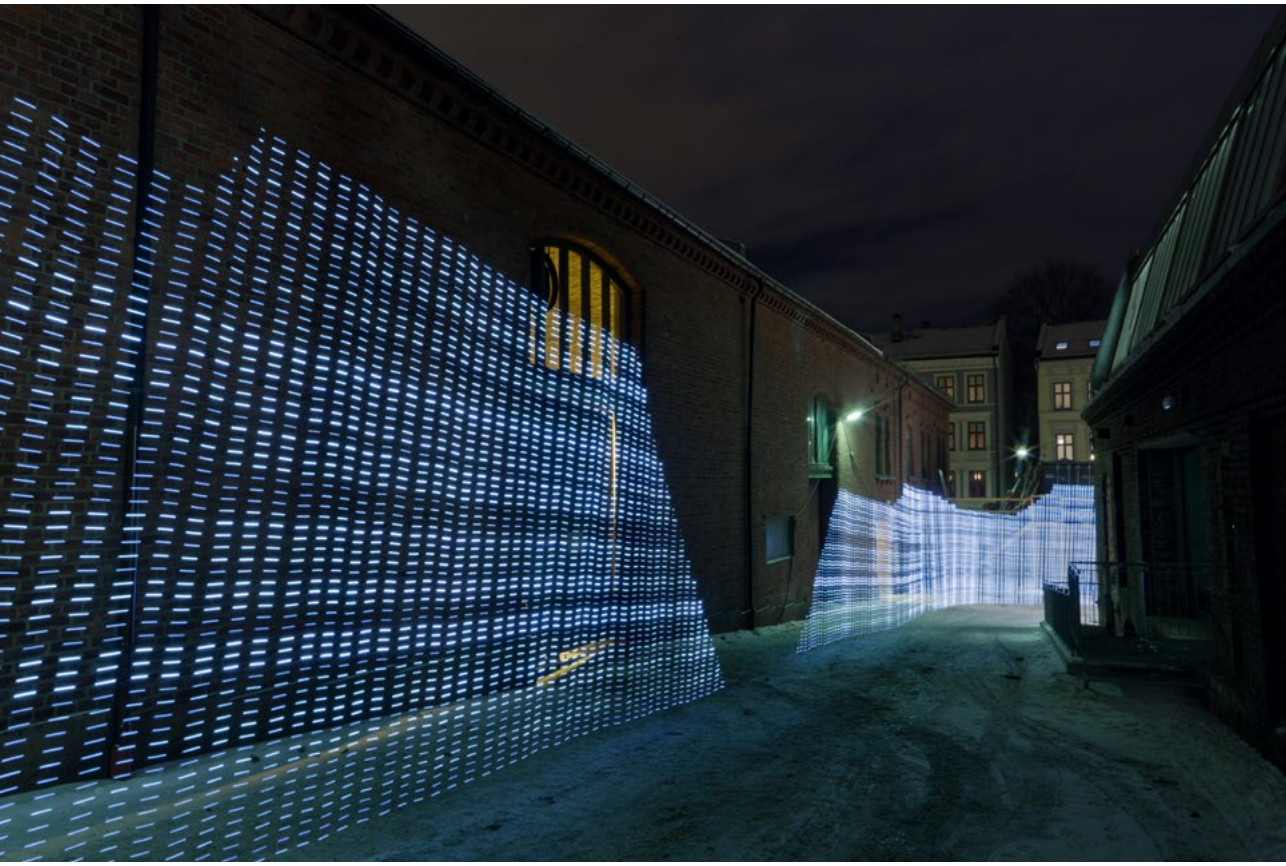

Figure 49: A still from the film *Immaterials: Light Painting WiFi: https://vimeo.com/20412632*

We have ourselves extended the approach to other interface technologies. The immaterials project is continuing in new research contexts: we have investigated both WiFi and GPS. These technologies have very different material and interactional qualities from RFID, so required different visualisation and communicative approaches. WiFi for instance, as seen in the film *Immaterials: Light Painting WiFi* shown in Figure 49, operates over a much larger area, so required a larger technical probe, but also new photographic techniques inspired by urban landscape and architectural photography. These required different kinds of visualisation and mediations.

Figure 50: A still from a film produced by Copenhagen Institute of Interaction Design students (supervised by Timo Arnall) called *Visualising Electromagnetic Fields*: https://vimeo.com/65321968

Most significantly, others have been inspired to take up the techniques and to extend them to other technologies and contexts. The approach to WiFi was reproduced by the BBC, extended to measure not just WiFi but 3G and other radio waves. Students at RMIT, MIT and CIID have used the technique to visualise electromagnetic fields around everyday electronic products (see Figure 50), detailed further in Article 1 (Arnall 2013 in press).

Mediational materials of other emerging technologies

I end this Chapter on approaches with an anecdote from towards the end of this research. This anecdote comes from the production of our forthcoming film, *Satellite Lamps* (Martinussen et al. under review 2014). The production of this film illustrates how a mediational materials process loops through the three approaches of culture, materials and communication and how this extends to other technologies.

Having produced two pieces of work on revealing immaterials, *Immaterials: Ghost in the Field* and *Immaterials: Light Painting WiFi*, there was a third wireless technology that had significant impact on mobile interaction design that we were curious about: Global Positioning System (GPS). Given how central GPS is to daily interaction with smartphones, from finding where you are on a map, to providing local recommendations, even triggering reminders and alarms, we have very little knowledge about how GPS signals inhabit our physical landscape. Apart from observing a blue dot bounce about on a map, the underlying qualities of GPS signals in urban environments were largely unknown. Taking our experience in visually mapping RFID and WiFi, we decided to see what GPS signals would look like if painted using similar approaches.

Figure 51: The 'GPS heat map' rig, designed to draw the signal strength of GPS signals as a giant light-painting across the ground.

Figure 51, above, is an enormous light painting rig that we developed to show GPS signals along the ground. We wanted to produce heat-maps of GPS signals, because we felt that heat-maps were widely known as a visualisation tool in contemporary digital cartography: traditionally used in weather forecasts, they are now used to show phenomena like crime or pollution in a similar manner. But even though we tried and experimented incredibly hard to find colours, densities, patterns and locations that would give us heat-mapped visualisations we could not generate images that were explanatory enough. We realised that heatmaps were complex, difficult to explain and that there were visual problems with such approaches, such as interference of textures and the confusion between green light and grassy surfaces.

Figure 52: A light-painting of GPS signal strength using the 'GPS heat map' rig.

In Figure 52 you see one of our first heat-maps of GPS signals. Although it is an intriguing image, and somewhat spectacular, we realised that the image was simply too complex and ambiguous to be properly communicative. It also shows how GPS signals are not only spatial, but temporal. The green 'blip' under the bridge could have been caused by the physical 'GPS shadow' of the bridge, or could have been caused by a satellite moving in the sky or disappearing over the horizon.

Figure 53: The final design of a 'Satellite Lamp'. This lamp changes brightness according to the accuracy of the GPS signals it detects. When we film it over many hours, as a time-lapse, we get mappings of GPS signals over time.

We threw away a great deal of design, development and experimentation in order to simplify the visual and cinematic representation of GPS. In Figure 53 above, the final Satellite Lamp is shown. This visual form was chosen because it can be easily explained as a lamp that changes

brightness according to the accuracy of GPS it detects, where good signals are bright. By changing our mapping technique from spatial to temporal, from light-painting to time-lapse, we also found a cinematic technique that was much more immediately legible and that would not require any explanation. The film and further reflections on it's cultural and technical implications can be seen in Article 3 (Martinussen et al. under review 2014).

These "curious, investigative and exploratory" (ibid:n.p.) approaches at the heart of our design practice set up "a space in which design can be about engaging in the meanings and language around the technology." (ibid:n.p.). Further,

> we use design not – in the traditional sense – to find new or better uses of a technology, but we use the methods, skills and knowledges within design to understand and communicate about the technology. (ibid:n.p.).

The approaches to GPS in *Satellite Lamps* show that, in a mediational materials approach, there are not separated processes of material exploration and mediation. They inherently connected; the communicative approaches and techniques of mediation are the means through which we reflect and analyse the material. These intricately intertwined approaches are able to purposefully engage with the existing meanings and materials of interface technologies like RFID, WiFi and GPS in order that we can stage more informed public discussions around them.

Chapter 4
Reflections and conclusions

In this chapter I reflect on the three approaches in mediational materials, and offer conclusions on the implications of these perspectives.

Technocultural perspectives on RFID

RFID is a literally invisible technology; its physical, material properties support the rhetorics of invisibility and seamlessness in ubiquitous computing interfaces. As the prototypical technology that is seen as a building block of an 'internet of things', RFID has helped create a popular design culture in which invisible interfaces and seamless transactions are seen as the future of good design. However, as many have argued, invisibility and seamlessness are problematic concepts that have consequences for our agency over, and understanding of, technical systems. There are challenges in understanding and revealing systems that are designed to be 'seamless' and whose dominant visions are about transparency and invisibility, that have removed "our knowledge of the glue that holds the systems that make up the infrastructure" (Ratto 2007:25). As designer researchers we are now faced with the challenge of re-discovering the seams and materiality of these systems through the explorations of their visual and material phenomena.

By instead adopting technocultural perspectives on RFID, I have challenged some of the visions of technologies as seamless, and have begun to generate an epistemology of how "we are constructed as subjects, what types of systems are brought into place (legal, technical, social, etc.) and where the possibilities for transformation exist." (Ratto 2007:25). Similarly Balsamo says that "designers must employ techniques for elucidating the meanings that cohere within a particular technocultural formation, because these elements will inevitably become part of any resulting assemblage." (2011:13). It is only through a process of exploration and revelation that we are able to develop our 'object-world' understandings as designers, in order to assemble new perspectives on, and meanings around, emerging technology.

By investigating RFID as a visual and material phenomenon, through photographic studies and visual analysis, I have revealed the symbolic and representational aspects of the way that the interface technology

is externalised through visual means. These visual symbols for RFID provide designers with a repertoire of visual material, a rich source for understanding and shaping our shared technoculture. Building a resource of these images, through online, shared archives acts as a pragmatic resource for designing, but also as an argument for increased attention and reflection on the technology.

Material perspectives on RFID

As described in Chapter 2, the concepts of digital materiality most often focus on the nature of software, the fluidity and immateriality of which has been problematic for theories of interaction design material. However, technologies such as RFID, that have inherently spatial and physical properties, allow for a re-evaluation of more traditional design perspectives on materials, to developing new approaches towards physical materials in interaction design practice.

The visualisations contained in the films are multi-mediational works that are designed to intervene in the abstraction of RFID technology, its solutionist rhetoric of seamlessness and invisibility. By designing and showing alternative perspectives, by playfully using RFID to remix existing media tropes, and also by investigating the technical phenomena through visualisation. All of these designed interventions were intended to intervene in the cycle of technological reproduction by examining the technology from alternative angles. The intention was to reopen the black box of RFID in a way that problematise simple 'RFID is' and the 'RFID does' kind of statements. In their material approach, these projects relied on actual implementations of RFID technology and were the result of extensive technical development. In this way they are unlike many critical design projects that are pure conceptual speculation around the implications of technology.

In having this material foundation, they open up the technology for discussion, engagement, critique and argumentation in a manner that is very different from critical design. They do not speculate about the social, cultural or political implications of the technology, and instead argue for a material perspective, that can be applied to many technologies and contexts.

Communicative perspectives on RFID

Although theories of communication have long since moved away from modernist visions of transmission and process, industrial and interaction design research still too often holds on to these models of communication as seen in Crilly et al. (2008). A means of accounting for the richness and complexity of communication in both designed artefacts and in design processes is needed. In fact, what I have shown through our approaches in Chapter 3, is how central communication can be as an analytical and productive means of engaging emerging technologies in design research. An approach to seeing the mediational aspects of design research: the ways in which tools and signs are used in the learning about, and development of, interface technologies is an important perspective.

The exploration of RFID interfaces in this study took the approaches of research by design, technological reproduction, as well as technological mediation and remediation to produce a series of visual works. These were mainly photographs and short films, but also multi-mediational works that were produced as weblog posts, online journal articles, presentations and exhibitions. Article 3 reveals how

> we use techniques and strategies from the discipline of interaction design to disseminate research and to convey the processes of interaction-based inquiry. (Martinussen et al. under review 2014:online)

By pragmatically and provocatively taking visual design approaches to RFID technology, I have argued for new, legible perspectives on technology, approaches that instead of 'deliberately making invisible', use visual approaches as a means of analysing and constructing new perspectives on the technology. These moves focus attention on existing visual communication of RFID interfaces, and experiment with novel ways of visualising RFID, open up for learning and development in design practices. They also open up for learning and reflection across disciplines. The visualisations are intended to be open-ended, they are not designed to be definitive 'solutions' to designing with RFID, and instead to catalyse discussion and to inspire new explorations. This is in line with how Ewenstein and Whyte see the function of visual representations in design processes. In their view the creation of epistemic objects as visual representations "gives rise to a range of questions that demand coordination and collaboration across domains of knowledge or epistemes." (Ewenstein & Whyte 2009) They see visual representations

as essential in innovative contexts, where they act as pivotal practices in design knowledge development.

The social semiotic perspectives that see interfaces as mediational objects, instrumental tools surrounded by signs, allows for design research to analyse the cultural meanings around emerging interface technologies. This perspective gives designer-researchers the opportunities to both study and to shape the meaningful aspects of emerging interface technologies. If these signs are not just the shape of the interface itself, but its related mediations in cinema, television and other media, this becomes a rich resource for design research and practice.

Towards discursive design

The design explorations in this thesis have exemplified ways in which designers can participate in reflexive conversations about the materials and the invisible aspects of ubiquitous computing technology. This is possible through addressing socio-cultural concerns through dialogical, material and communicative modes of design, that requires both practical and analytical intersections in designing and reflection. This kind of discursive design bridges between technical and the cultural domains in interaction design and communication.

It builds upon some of the traditions of critical design but focuses on generative, constructive approaches to material and communications, the "reflexive and iterative interplay between materials, experimentation, and use" (Morrison & Arnall 2011:226). The explorations show that interaction design is not a practice of 'problem solving', but how it can instead build language, narratives, and communicative material that, through chains of visual and material artifacts, translate between complex technical subjects and broader audiences and discourses. In this discursive perspective on interaction design research, we are able to explore, reveal and discuss RFID interface technology without obscuring or mystifying underlying complexities.

As Balsamo states, "cultivating and shaping the technological imagination is a cultural imperative of the highest order." (2011:247). Through the development of expert practices in photography, animation, filmmaking and social media, interaction design can transform tacit, obscure and technical knowledge into communicative, discursive material. The communicative outcomes of these processes are designed

to both explain and reflect upon technical materials and our approach to understanding them. In this process we take up the culture and materiality of the world, and actively remediate it through "the development of new narratives, new myths, new rituals, new modes of expression, and new knowledges." (ibid:237). In this kind of discursive design approach, we account for the material and mediational aspects of design that engage in the technological imagination.

In our view, discursive design aims to open up for sharing, negotiation and discussion of Bucciarelli's 'object worlds' beyond the boundaries of the design studio or workshop. To bring these materials and methods, the meaningful bits of those object-worlds, to the surface, to use them as critical and discursive materials. This is different from critical design (Dunne 1999), in that it does not have to take a critical view, or invent 'everyday' products as critique. It is not adversarial design (DiSalvo 2012) in that it does not have to take adversarial positions, use protest or necessarily radical political positions. It is also not speculative design or design fiction (Kinsley 2010), in that it does not rely on fiction or speculation as its material or outcome.

The mediational materials of discursive design are different from critical design in that it offers a pragmatic and open-ended revealing of the materials inherent in technical development, for designers and for culture. Yet, it is a critique of the dominant discourses and imaginings in engineering and technical domains, opening up obscure and mundane technologies for study, discourse, playfulness, conceptual design, and new explorations.

Discursive design engages with the popular cultural imagination, and is concerned with the socio-cultural representations and mediations of technology. We need a practice that is able to unravel, reveal, visualise, invent and mediate emerging technologies through their materials and allow for others to interpret the potential futures they may anticipate. Interaction design practice and research offers a mix of methods, approaches and conceptual frameworks that is able to do this. As Murray suggests, by looking at computer-based artefacts as media, we can see that they can be

> aimed at complex cultural communication, in contrast to the instrumental view of computational artifacts as tools for accomplishing a task. (Murray 2011:8)

Discursive design operates as a trans-disciplinary practice through the use of online tools such as weblogs, online video, photography and social media. It engages an enthusiastic following of researchers, designers and others in related disciplines, crossing between communities of practice and encouraging trans-disciplinary collaborations.

Part of the role of design research should be to contribute to cultural expression, to create the material around which cultural debates can occur, and to invent and participate in the culture in which these meanings and mythologies are created and taken up.

Limitations, tensions and issues

There are a number of issues and tensions in this work which are worth expanding on. The issues here are whether these mediational, material and communicative approaches are applicable to other emerging technologies or to different kinds of interaction design material such as software, and whether they can directly address application, use or user-centred issues around emerging technologies.

This thesis has deliberately taken up the study of RFID, and extended it to WiFi and GPS. These are still often called 'emerging' technologies but they are distinct in that they are all more or less quite stable that are in use by millions of people every day. Thus it would seem that these approaches are best suited to studying technologies which are emerging in cultural as well as technical ways, that are already part of everyday and popular culture. It might also be possible to extend these approaches to older technologies, a study of electricity or combustion for example, but it is not clear if it can be applied to newer and less established technology. For instance nano- and bio-tech do not have a lot of existing cultural meanings or interpretations and it might be difficult to be able to engage and enquire about technocultural issues without sufficient source material. To approach these kinds of technologies perhaps we need to develop techniques for analysis and production across technical boundaries, so for instance taking the cultural phenomena of electricity and applying it to bio-tech. As can be seen in the output of the Royal College of Art 'Design Interactions' course, critical design is currently taking on these less-developed subjects using techniques developed by Dunne (1999).

By taking this cultural and material-centric approach I hope to have given a richer account of RFID that articulates it more as a generative material than as a conceptual technology. Although I have hinted at the possibilities for this kind of exploration in other technology and design disciplines, it may not be suitable or applicable to other kinds of technical phenomena or to other disciplines. Although there are emerging approaches to using visualisation and animation for learning complex systems (e.g. Hansen et al. 2000), appropriate visual simplification and abstraction is difficult, particularly in explaining complex and amorphous systems such as software or infrastructure. Software behaviour for example might remain best described as a 'material without qualities' in order to avoid unnecessarily limiting what remains an extremely fluid and changeable medium. In order to account for higher levels of complexity and abstraction, we may require other sets of creative, inventive tools and approaches. These domains are more suited to interactive visualisation and explanation, such as the dynamic visualisations for understanding systems by Victor (2013), than the still and moving images used here.

This study has addressed the specific case of RFID technology that, while important and a central building block of many ubiquitous computing systems, has particular physical material properties. In the other aspects of this study, the exploration of WiFi and GPS, we revealed the physical and temporal qualities of these interface technologies. So, the techniques I have developed reflect a particular kind of material exploration, that explores the invisibility of physical wireless technologies. These approaches would not be applicable to the behaviour of software for instance, or the multi-dimensionality of a data-architecture. They are specifically developed to reveal invisible otherwise spatial and temporal phenomena. So the problems of materiality of code and of data remain to be explored and explained through other means, and these studies should follow in the footsteps of Armitage (2009).

As suggested by Fernaeus and Sundström (2012), in contemporary interaction design technical design materials change rapidly, so the knowledge generated here may be contingent and time-limited. As RFID technology develops, its material phenomena may change. In this case I hope that the creative approaches and explorative nature of this study remain the key finding, and that design research will take up new technical development as an opportunity for further material exploration.

Material exploration is an approach that can be used to explore and discover the materials of interaction design, but what if the development digital materials becomes more codified and stable? If material knowledge becomes a more stable and shared understanding, it becomes less of an issue to explore it as part of every project. This limitation could be seen as a challenge and opportunity for interaction design research to focus its attention on material issues in order to achieve a stable, productive status, with a known material repertoire.

I also recognise that much of this kind of deep material exploration has been produced in a rarefied, Nordic academic context, and that it may not be applicable across different kinds of design practices and contexts. In my work as part of the commercial design studio BERG we successfully conducted many material explorations in collaboration with our clients (such as Armitage 2009) including Intel, Google, and Ericsson. In other commercial or industrial design contexts however, there may be significant concerns such as business needs, user needs, etc. and a process of material exploration of technologies may be outside the design brief.

Despite the simplifications and abstractions inherent in these approaches–both in the visual abstraction of the practice, and in the theoretical framing–it is important that these approaches are only seen as partial descriptions and particular perspectives. The approaches here may not produce more efficient RFID technologies, or offer easy 'solutions' to improving RFID-based applications. I do not directly address the use or application of RFID, or the usability of RFID systems. Instead the outcomes require interpretation and discussion. Through their communicative, culturally-situated modes they are designed to provoke discussion, learning and development, and to provide a framing that can be shared and contested without reproducing the declarative discourse that has previously defined much of HCI and informatics research.

Conclusions

This thesis has taken up the analysis and production of RFID interfaces through a combination of material and mediational approaches. It has taken up the question of how interaction design research can engage with RFID as a technocultural phenomena, both through analysis and production of new, communicative material. The central research question that this thesis addressed is

How interaction design as a communicative and material practice may intervene in the technocultural imagination of RFID?

To answer this I have taken up three approaches. Firstly I have shown that design research can approach RFID as more than instrumental interfaces, that we are also able to see it as a cultural phenomena, with complex and varied meanings, symbols and communicative representations. Secondly I've shown how we can generate new perspectives through a material approach to RFID technology, exploring and revealing technical design materials through visualisation. Thirdly I have also shown how these approaches are connected through communication, and how we generate and share new meanings and address the technocultural imagination by working through communicative practices. I have highlighted how a technocultural approach to analysing, describing and exploring technologies is central to this culturally-inflected design research practice.

From instrumental to mediational approaches to RFID

As I have shown RFID is a complex and contested assemblage of technical development, marketing speculation, everyday cultural understandings and protest. But the dominant discourses, particularly within design and HCI as shown by Rosol, have always been and continue to be highly instrumental views of the efficiency, control and ubiquity of RFID interfaces such as those shown by the Auto-ID centre at MIT. In response the mediational material approach outlined here has uncovered, explored and shaped a more design material-centric perspective on RFID. This has shown that RFID is already taken up, interpreted and understood as a cultural phenomena, its meanings and mediations very different from technical understandings. It has also shown that the meaning of RFID can be shaped through interaction design practice and research, through visualisation, media and communicative practices.

These mediational materials have been taken up in culture not as definitions or declarative statements, but as partial new descriptions and situated understandings that are the foundations of discussion and critique. Their use in teaching, talks, exhibitions, in textbooks and coffee table books, on broadcast television, as embedded in online media and discussion, have allowed for further mediation and remediation. They have worked towards taking these perspectives to broad audiences, both to provide new mediating, epistemic artefacts that develop knowledge, learning and discussion. They gain their persuasive, rhetorical power by responding to and reflecting upon existing meanings, understandings, representations and interpretations in culture, by working through both

Bolter and Grusin's concept of remediation and Balsamo's concept of technocultural reproduction.

In opposition to the largely speculative visions of critical design, or the spectacular and exaggerated visions of technology marketing, these mediations are based in the exploration and evidence of material phenomena. Although they are not strictly documentaries, and not conventional 'documentation' of the design process, they are closer to the documentary genre than they are to design fiction or critical design. They could in some ways be compared to nature documentaries that use novel techniques such as timelapse or slow-motion as modes of exploring and recording the phenomena of the natural world. But by using the same high-production value techniques as high-end advertising, cinema and photography we situate the work alongside the spectacular media tropes of contemporary media. We use this ability to situate these new views of technical design materials alongside the visions from Apple, Microsoft and Spielberg's Minority Report. Unlike more technical or specialist design understandings, they are able to speak more broadly through this remediation and articulation of multiple cultural themes, tropes and representations like signage, light-painting, time-lapse and cinematic genre.

The agency of design materials

As Schön describes, design materials, including these in interface technologies, 'talk back', they have significant non-human agency in design practices, and also in the way that they manifest in everyday life. Designers cannot impose their will on interfaces like RFID outside of the constraints of the material itself. In these 'heterogeneous relations' (Law), interfaces impose their material qualities on people (especially designers), requiring them to fit into their technical affordances and constraints. Making this agency visible, through means that address broader, cultural concerns, not just the preoccupations of designers or engineers, means that this agency can be perceived, discussed and critiqued.

The means of making the agency of interface technology visible involves the three interconnected practices of mediational materials. Without the ability to explore existing meaning and mediation of technology, through its existing interfaces, signs and symbols, we're not able to see how it is already inhabiting the world. Design practice has methods for exploring and documenting these mediations, but we need to account for it in design research. Here the concept of reproduction and remediation

are important, in that they help account for the ways in which interfaces are designed through the re-use and remixing of existing concepts.

By enacting the three approaches together, designers can shift the power over the development of technology, specifically by altering the representations and meanings around that technology. By concentrating attention on the materiality of interfaces, rather than other perspectives such as use, potential, or implications, it is hoped that this creates spaces for reflective conversations with and about these technologies. The creation of culturally resonant images of technical materials in itself speaks for the agency of materials in shaping interaction and interfaces. The films and icons have shown how culturally resonant images and narratives about the materials of RFID can assemble diverse and constructive conversations across many communities.

Through these acts of making visible, design can be seen as a practice that shapes the technocultural imagination of interface technology, not just the imagination of products and services. Given the lack of other means of producing such material, design research should recognise the importance of exploration and communication of interface technology as a social and cultural imperative.

From digital materiality to design materials

In Chapter 2 I outlined the material turn in interaction design, and that attention is returning to the issues and concepts of materiality. The discussion of digital materiality has so far been concentrated on typological, epistemological and semantic issues around the concept of materiality in digital design. The problems of (im)materiality in software and in other so called 'immaterial' practices have been the focus of Leonardi, Dourish, Löwgren and Stolterman and others. But I instead have proposed that we instead return to more pragmatic approaches and definitions of design materials drawn from the design practice that I have outlined in this thesis. This is possible because digital materiality is becoming physical once again, through tangible and sensor-based interfaces, physical materiality becomes central.

This approach highlights the material aspects of design practice with digital materials, the ways in which otherwise 'immaterial' phenomena may be explored, visualised, understood, shaped and shared. Beyond re-defining 'digital materiality' there is also the importance of representing and sharing of materials in design practice. Once we treat previously amorphous and ill-defined digital materials as just design materials, we once again are able to see the importance of a practice based in a

'conversation with materials of the design situation'. We are able to see these technical design materials as central to inventive, creative and cultural design practice with emerging technologies.

From seamlessness to legibility

The concept of seamlessness in interface technology has been useful in creating systems, infrastructures and interfaces that are less technical and less complex in use. However, in reducing complexity, this has increased the abstraction of technology away from its material foundations. This has had direct consequences of increasing the invisibility of technical infrastructures, and this move has been broadly criticised by scholars like Hjelm, Fernaeus and Ratto. In these critiques, the shift of power, agency and control away from users and designers, and the potentials for misuse through 'double-invisibility' have been shown to be highly problematic. In response I have shown a set of material and mediational practices that aim to increase the visibility and understanding of interface technologies. They aim to increase legibility of infrastructures like RFID, WiFi and GPS in order to gain material understanding for our own design practice, but also for new agency, new forms of control, discussion and debate across disciplinary boundaries.

Although these material mediations are only partial descriptions, and I have not aimed to provide comprehensive new views or approaches to understanding or designing with new technologies, they do provide new perspectives and situated approaches to technologies that have been taken up widely across design and other disciplines, and into and through popular culture. In the case of RFID the visualisations provided accurate 'evidence' of a previously amorphous phenomena. In the case of WiFi the visualisations gave us less concrete 'evidence' but more situated understandings of previously unseen infrastructural landscapes. In our work with GPS we have seen glimpses of the temporal landscape of satellite signals, not a complete picture but pinpointed, situated samplings that give us a sense of the 'grain' of GPS as a material that is otherwise illegible.

These mediational materials are based in explorations of technical phenomena, they are grounded in both the technical reality of these interfaces and in their physical, social, urban contexts. They are not intended to remove the need for abstraction or invisibility of interfaces, but they do provide a foundation upon which it is possible to conceive and design better abstraction and more helpful mythology that is based on the underlying 'grain' of the technical material.

Perhaps the most important outcome, and the most rewarding experience for us as designer researchers, has been the way that this has stimulated and provoked mediational material approaches in other groups, communities and disciplines. It has stimulated new research into both visible interfaces and visible processes. New, experimental and explorative approaches have been developed towards other technologies, to other practices in other domains and by other communities. This most of all has shown them to be valuable conceptual, analytical and practical approaches.

Implications

Why is it important for design to investigate the material and mediation of interfaces such as RFID? Invisible interfaces and their infrastructures are proliferating in enormous quantity and variety into the physical world, with increasingly complex and pertinent roles in everyday life. The intense development effort into new radio-based infrastructures, and into physical sensing interfaces means that signs point towards interaction becoming increasingly ubiquitous, physical and invisible for the foreseeable future.

Material knowledge of these interfaces is crucial in order to understand these interfaces as part of the world, and to find out where opportunities for intervention and transformation might occur. The components that form the substrate for the invention of new interactive products may be literal black-boxes, but that does not mean that we must accept them as stable and given. Finding representational means, through visual signs and symbols is also a central issue for interaction design, we need ways of representing these technologies to ourselves so that we can re-imagine them. There is also a pragmatic need to make these interface technologies visible in order to reveal, instruct and explain to users.

This study has demonstrated that RFID interfaces can be researched through experimental and exploratory methods in materials and mediation. It has been possible to build analytical and practical insights into RFID through these methods, even though they are drawn from disciplines as far apart as ubiquitous computing and comic book illustration. A necessarily broad analytical approach is required in order to account for the mixture of interface culture, technical material and visual communication that makes up the landscape of an emerging technology. I sum up by returning to the three approaches that are explored in this thesis and summing up the implications and theoretical concerns.

First, I have shown how RFID is predominantly seen as an instrumental interface in much existing research, and how it forms the foundations for much thinking about the future of interaction and an 'internet of things', where interaction is seamless and invisible. Meanwhile through the lens of popular media RFID is seen as a symbol of control, generating excitement and fear that is often detached from its material or practical reality. This combination of invisibility and polarised controversy in the cultural understanding of RFID, is something that can be addressed by design research. By analysing these things as technocultural phenomena, we are able to address them as part of our design research process, to explore and gain understanding of their culturally-situated meanings and representations. Without this kind of knowledge we are less able to understand how we address an emerging technology outside of instrumental, purely speculative or solutionist approaches. This process of investigation is foundational for the exercise of the technocultural imagination: for being able to account for culture as part of technological innovation and interaction design.

Second, by exploring RFID as a design material, with physical and spatial qualities, I have emphasised the importance of material approaches in design with emerging technologies. Existing material concepts drawn from contemporary design research give us some insights into materiality but do not analyse the generative nature of materials, or the way that we are able to communicate about them. If innovation happens in the entanglements of the technical and the cultural, as Manzini and Balsamo suggest, material exploration can be a valuable part of the design process, particularly to help balance a discipline that is currently predominantly user-centred. I have demonstrated how the practices and processes of interaction design may draw on historical approaches in industrial design and scientific investigation in order to make technical phenomena visible. Through the processes of *material exploration* and the concept of *immaterials* we are better able to see material as part of interaction design practice and research, and to frame it as a central part of our processes.

Third, by focusing on the communicative and mediational aspects of these technical phenomena, both in the analysis and production of design work, I see interaction design as a discursive practice. Although approaches to communication through graphics, visualisation, film, photography and language are already widespread in design practice, communication could be more fully recognised as an analytic and productive tool in interaction design research. As a discursive practice, interaction design can take up existing symbols, meanings and discourse

in culture as a means of understanding and shaping technocultural phenomena from many perspectives. It then explores those phenomena by creating and producing mediational, visual and narrative means, in order to articulate new culturally resonant meanings. This creative work is produced towards specific audiences such as related design and technology specialisms, but also towards a broader audience using the genres and 'languages' of animation, film and television. In this way it aims at engaging in the popular technocultural imagination, providing new perspectives grounded in the material investigation and evidence.

Overall this research shows the connections between the three intertwined analytical modes of research: investigating the technocultural, exploring design material and the mediational potential of creative and communicative design processes. Together they illustrate a discursive mode of design research that takes up the cultural and the technical, and addresses it through material and communicative means. They have been used here to investigate the phenomena of RFID technology, to reveal the problems of invisibility and address it through material and communicative analysis and production. But these approaches also continue to open up for further explorative and experimental material and visual work, new explorations and provocations that continue to make our technological landscape more legible and material.

Articles

This thesis includes four publications, all journal articles, that explore visible and invisible interface technologies through perspectives that develop material and mediational approaches. They are presented here in the order that they were conceptually developed, rather than the order of publication, that best reflects the argumentation in this thesis.

In developing these articles, I favoured online publications in which images and videos could be used extensively, and one article, Satellite Lamps, is an entirely digital, multimedational publication, developed through digital tools, filmmaking and image-making. With the exception of Article 1, all articles have been written collaboratively with colleagues and members of the Touch project. This reflects the collaborative, networked nature of a complex digital design research project.

Article 1: Exploring 'immaterials': mediating design's invisible materials
This article takes up the issues of so-called 'immaterial' and 'seamless' technologies and asks how designers might explore them in order to consider them as design materials. It also questions how both material and mediational approaches might contribute towards shared knowledge of RFID interface technology, both in design and as a means of discussion across disciplines. It situates interaction design as a sociocultural practice that is concerned with culture, critical approaches and with engaging the technocultural imagination. It demonstrates how visual material around RFID was created using technical probes, animation and filmmaking processes. It concludes by analysing its mediational strategies, such as the use of documentary formats, online film and weblog writing, and the ways in which new material perspectives have been shared, discussed and developed by others.

Arnall, T. (in press). 'Exploring 'immaterials': mediating design's invisible materials'. *International Journal of Design*, 29.

Article 2: Visualizations of digital interaction in daily life
This article explores how visual signage may make aspects of ubiquitous computing technologies visible and how digital tools and platforms impact that visual design and semiosis. It looks at a range of 'identification' technologies such as barcodes and RFID, that only become 'visible' or 'interactional' through a designer's intervention in physical or visual expression. This visual 'mark-up' of the technology becomes

an important discursive design manifestation that communicatively uncovers hidden materials as well as potentials and implications of the interfaces. It finds that designers should emphasize the bindings and distinctions between design processes and visual mediations, and symbols and signs, in engaging with emerging technologies as material for creative and communicative composition.

Morrison, A., & Arnall, T. (2011). Visualizations of Digital Interaction in Daily Life. *Computers and Composition*, 28(3), 224-234.

Article 3: Satellite Lamps
Satellite lamps is a project about using design to investigate and reveal one of the fundamental constructs of the networked city: GPS - the Global Positioning System. It extends the concepts of 'mediational materials' to an investigation of the ways in which GPS technology inhabits urban spaces. The central output of this project is the film *Immaterials: Satellite lamps*, that visualises GPS as a material and spatial phenomena. The article takes up how a discursive and reflexive interaction design practice can contribute to new perspectives on networked city life. Overall, *Satellite Lamps* exemplifies and argues for a discursive and reflexive design practice that constructs many different kinds of visual and mediated representations, that is created from a broad collaboration of design and media skills.

Importantly, *Satellite Lamps* is a multimediational web text, involving different media (film, media, notebooks and a host of images) allowing for the richness of the work to come to the surface in a way that would not have been possible in traditional means of academic publishing.

Martinussen, E, Knutsen, J & Arnall, T. (under review 2014). Satellite Lamps. *Kairos: A Journal of Rhetoric, Technology, and Pedagogy.* http://www.technorhetoric.net. Retrieved December 17, 2013, from http://ruby.voyoslo.com

Article 4: Depth of Field: Discursive design research through film
This article is about the role of film in interaction and product design research with technology, and the use of film in exploring and explaining emerging technologies in multiple contexts. It gives a discursive account of how film has played an intricate role in our design research practice, from revealing the materiality of RFID technology, to explaining complex technical prototypes, to communicating to a public audience through online films that may fold broader social and cultural discourses back into the design research process. It concludes by looking towards the potentials for a discursive design practice, where the object of design

and analysis is the discourse that is catalysed by new artefacts, and the emphasis of design research is on communication.

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