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Current Issues and Future Directions in Methods for Studying Technology in the Home

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ABSTRACT

Homes are essential contexts in which to understand how technologies are used and experienced. At the same time they hold substantial challenges for conducting research, exploring novel designs, and building understanding. In this paper we review approaches to studying the home, including recent innovations and issues that should guide further methodological reflection. We draw on the expertise of a large number of researchers experienced in studying technology in the home, who have formed a community to map the space of methods in use and share their experiences of the key issues faced in practice. Themes include utilising new technology as a source of data as well as an object of study, creating representations of home life that support discussion and reflection, revealing details of important yet routine or mundane activities, and supporting participation to overcome the complex ethical and privacy concerns inherent in the study of the home.

Keywords: *Home, Research Methods, Human-Computer Interaction*

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1. Introduction

Studying interactions and experiences of technology in domestic spaces presents a range of challenges, such as understanding social complexities, the diversity of home

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environments, and privacy. In response to these challenges, it is important to bring together cross-disciplinary expertise in researching technology in the home, to reflect on the knowledge(s) gained through combinations of theories and methods, promote rigour in methodological developments and integrations, as well as explore the potential for further innovation (Coughlan et al. 2013b). Here we reflect upon the current state of the art in research in and around the home. Particular themes present themselves across a number of the methods used, including the need to capture household routines and practices that may be considered mundane and thus unmemorable, how interventions in domestic life raise ethical and practical issues, understanding the importance of boundaries in the home, but also their extended or porous nature, and also coping with micro or macro changes, shaped by complex social interactions over time.

In the following sections, we map this methodological space with reference to a range of innovative projects, and to the common issues raised by researchers experienced in studying technology in the home.

2. Research Challenges

In this section we begin to unpack some of the challenges that face research around technology in the home, in order to build understandings of the types of method developed in response.

2.1 Home as a dynamic and extended semi-private space

A research challenge common to cross-disciplinary work is the semi-private nature of the home environment. People living in the home have diverse and dynamic perspectives on which areas and activities within the home are personally private, private within the household and with selected others, or fully public. For example, a child of 10 may see their bedroom as a relatively public space where friends and family can come and go freely, but as they become a teenager these views could change radically, with their bedroom becoming a deeply personal space in which only the closest of friends are welcome. This semi-private nature is also dynamic over the short term: during a party many areas of the house temporarily become far more public spaces, which visitors can legitimately inhabit. This dynamic level of privacy not only adds complexity to any study wishing to understand the use of space in the home, but

also has implications for the ethical collection of data in spaces whose purpose and occupancy change dynamically. For example, it may not be feasible for researchers to obtain informed consent for data collection from all possible visitors to a household. In some cases, researchers may consider whether and how participants can best share responsibilities for ensuring visitors' informed consent. In others cases, data collection may need to be halted if and when specific visitors are present.

Although our immediate conceptions are often tied to traditional shared home spaces, it is important to include non-traditional environments, such as independent living communities or student dormitories. Independent living communities are restricted to certain residents, but communal areas may be accessible by a variety of residents and their visitors. With the rapid population increase of the older adult age demographic, methods sensitive to such environments are important for collecting effective data. Challenges with such environments include reducing distraction, maintaining comfort levels and encouraging participants to provide feedback. Research in this area points to contextualising discussions, balancing distraction with natural interactions, and giving participants more control during data collection (Brewer, 2013).

It might also be necessary to study spaces such as gardens, which are private in ownership but often on display to the general public, and communal spaces such as shared walkways, stairs and lifts which offer a degree of privacy but are accessible to some outside the household. These spaces might be excluded from our standard conception of the home, but in many households play an important role in home life. Another space with an underexplored relationship to the home is the car. The utilitarian purpose of a car is for transportation, but research by Szostak (2013) revealed that the car was considered more like a "space" or a "state" rather than a device or machine. The car is a central space for individuals and families to spend time, and in many ways this is similar to the time spent at home. The car witnesses intimate human behaviours that are also carried out at home such as: eating, fighting with spouses or siblings, being entertained, sharing - from trivial to deep - conversations and moments with our loved ones, and even having sex. Furthermore, the car mimics certain areas of the home that blur the boundaries of public and private spaces, much like a living room with large windows on street level, or the front yard. The re-thinking of spaces such as gardens or vehicles as extensions of the home pushes the researcher to re-evaluate the methods utilized to study them. In the case of the vehicle, this difference signified that it could not be approached through methods used to study technology such as a

website, or wearable device, and being sensitive to the connection with the home opened the doors to thinking about evaluating in-car technology in a whole new way.

2.2 Ethical Implications and Participation of the Household

Above all, ethical issues around privacy should be considered and dealt with in studies of the home, as privacy can be considered as an essential quality in the concept of home, which implies a closed unit of community. In some cases, research interventions to homes could be considered to be a manipulation of household life. Even small technological changes may result in a major impact on the dynamics of household relationships and wellbeing. The potential for such effects needs to be considered both philosophically, and by means of concrete steps to deal with household tensions, loss of privacy or related ill feeling.

Tools for logging network traffic, or automatically recording devices and users, are viable (Martindale, Evans, Coughlan and Reeves, 2013), but an important ethical dimension is for the household members to understand the data collection process they are a part of, remaining aware of what is being recorded, when this is happening, and where it is stored. Monitoring technologies are designed to minimise inconvenience to research participants, by functioning independently in an 'always on' capacity in the background of daily life, and to capture 'natural' behaviour 'in the wild'. However, such research methods can still be regarded as intrusive on a conceptual level because they generate digital records of the home environment that will be removed from that environment and scrutinised from an outsider's perspective by researchers. And this potential for breaching privacy is true regardless of the nature of research interest in the home, although the degree is obviously dependent on the focus of attention and the sensitivities of individual participants. One way to address this issue is by combining methods of data collection, rather than trying to develop a 'one size fits all' solution. For example, network logging provides a picture of activity throughout the home without revealing contextual details, and this augments video recordings of interactions in the main communal space, which may be accessible to researchers in a way that interactions in bedrooms are not.

Novel processes by which data is held and shared can be envisaged, and it is important that these are evaluated as ever-greater amounts of data are collected through networked technologies in the home. The key ethical dimension here is that participants have agency in these processes, with consideration given to issues of ownership and control of research materials. There is a difference, for example,

between data that is stored locally on devices installed in the home, to which the participants allow the researchers access physically, and data that is streamed or downloaded remotely from the home without the need for direct interaction between participants and researchers. Equally participants should be given both the technical means and relevant information to review or stop data collection, without recourse to particular expertise or a gatekeeper, at any point and for any reason, as it may become an unforeseen source of friction or tension under particular circumstances. Unobtrusive tools for data collection could easily be perceived as enabling covert observation, which arguably places an even greater onus on consent than other methods of research involving participants, such as interviews, focus groups or ethnographic studies. Given that the research mechanisms are designed to become part of the commonplace backdrop of the household, in order to capture information about domestic routines, informed consent should be seen as an on-going dialogue with participants about what data will be collected when.

Treating consent as an on-going process in this context is one way to ensure participants' sense of control over both the research process and also the management of research materials. This is partly a matter of maintaining communication between participants and researchers, for instance by keeping participants informed about research milestones which, in turn, helps to manage expectations (cf. Yang and Newman 2013, for novel ways of participant communication). The notion of on-going consent is of further and particular importance with regard to materials that make conventional methods of anonymisation difficult, such as images and video recordings of homes and participants. Giving participants the option to edit or amend audio-visual data is paramount to creating a relationship of trust (Leder Mackley, Mitchell, Pink, Escobar-Tello and Bhamra, 2013). Additionally, it is good practice to give participants a sense of the specific contexts in which their data is being analysed and presented, for example by sharing work in progress. While it is not always practical to maintain these checks for the duration of a project, investing time and effort in processes of consent at the early stages means that participants are in a better position to evaluate and consent to researchers' subsequent uses of materials.

Giving participants agency in the research relationship is particularly important when trying to establish and maintain productive collaboration to enable long-term examination of user behaviour (and changes in that behaviour) in the home. A crucial component in this regard is the value that household members derive from participating in the research. While this may involve some form of material incentive or financial

compensation, it is also important to reflect on what other benefits, or indeed drawbacks, participation in the research might present. As Ogonowski, Ley, Hess, Wan and Wulf (2013) have discovered in their work with a Living Lab in the area of home entertainment, retaining participants over an extended study period and keeping them engaged presents a significant challenge, made more difficult if their expectations are confounded or their habits are disrupted. At the same time, it may be that the social experience of contributing to the research or the insights offered by the data and analysis are positive outcomes for participants as well as researchers, and steps can be taken to maximise this possibility.

2.3 Designing for the future

A significant challenge when studying technologies within the home is where the research is being carried out to inform future innovative products. Designing future technologies can be difficult as it is not possible to draw on current use and interaction with users, and in the home, subtle nuances, attitudes and routines may be a particularly strong factor in adoption. Innovative exploratory methods are needed to draw on past, related experiences to predict future reaction to, and use of, new technologies. It is an essential, yet complicated matter to support potential users to envisage how a novel domestic technology might fit into their own household context, given the importance of social, contextual and embodied factors to the experience of home. Approaches to tackling this issue are emerging (Coughlan et al. 2013a, Odom et al. 2012,).

There are many fields of design in which new technologies are being developed, many with innovative and fast changing markets. One example of this is seen in the rapid growth of energy saving technology development where there are many new technologies coming onto the market, but little feedback on their success. As many home improvement activities relate to energy saving, for example replacing a boiler, fitting new windows or carpets, draught-proofing or adding loft insulation, an exploration of past home improvement activities allows for a grounded exploration of the requirements for future technologies (Haines, Mitchell and Mallaband, 2012).

2.4 Capturing everyday life - the mundane

Another of the challenges encountered when researching within the home is how to obtain feedback and accurate recall of information and occurrences that are of little interest to the participant, or that are routinely carried out, making it hard to describe

particulars about such activities. Technologies that were once novel - such as a home wireless networks - eventually become an unremarkable part of the fabric of domestic life (Crabtree, Mortier, Rodden and Tolmie, 2012). One way of combatting this is to find ways to relate possibly mundane events or practices with something to which a person has more of an attachment, such as an emotional memory. For example, a participant may find it very difficult to recall when they installed a new boiler, however, if they are able to associate this with an event in their life, such as a birth, death or job change, it may prove much easier to recall not only the timing of the event, but also some of the emotions surrounding it (Haines, Mitchell and Mallaband, 2012).

Equally, ethnographic studies of the home can be especially useful in this area as they seek insights into everyday life as lived, with all of the minute and mundane complexities that constitute it. Where it is not possible for ethnographic researchers to spend extended periods of time in participant homes, the use of re-enactments can be a particularly useful route into situated understandings and the kinds of embodied knowledge that are difficult to recall or describe (see also 'Sensory Home' section). This method was, for instance, employed in the LEEDR project (Low Effort Energy Demand Reduction) where participants talked and walked researchers through their evening and morning routines, as well as through other pivotal moments of the day, such as leaving and returning home (Pink and Leder Mackley, 2012; Leder Mackley, Mitchell, Pink, Escobar-Tello and Bhamra, 2013). These routes through the home were video-recorded, with the home environment, including objects and structural aspects, providing useful prompts for reflection on routine activities. Similarly, LEEDR researchers video-recorded and engaged with participants as they went about everyday practices, such as doing the laundry, with the aim to gain a deeper understanding of active decision-making in relation to reflective and embodied knowledge (Pink, 2012).

Other research areas which rely on participants' active contributions to the research process need to, where possible, draw on methods that both engage participants and also make them feel that they have gained from taking part in the research.

2.5 Diversity

Finally, it should already be clear from the previous sections that homes and constellations of inhabitants vary on a number of levels. The work of maintaining the home is an on-going process (cf. Pink, 2004), and holds personal and specific meanings to those who live there. The household contains within it radically different

types of relationships that form a significant part of the meaning of the place, the roles observed and the activities that occur. These relationships evolve over time, and there are also temporary changes, such as visitors. Home environments vary significantly in terms of physical structures, ownership and control. Technologies already in place and in use will differ, even for similar types of home. Culturally, ways of thinking about home life are varied. For researchers this needs to be accounted for through flexibility in methods, and relationship building to understand specifics.

3. Domains

A wide range of domains are being explored by the researchers who contributed to this review. In some domains there has been long-term interest and extensive research. In other cases, technological advances or modern societal concerns prompt interest in new forms of interaction that need to be understood in relation to the home. Here we summarise major areas of home-related research, in order to provide context to our exploration of methods.

3.1 Pervasive Computing

Currently, a major research driver is the potential for pervasive computing technologies that are embedded into the objects around us. Visions of an 'Internet of Things' in which elements of the home, such as appliances, lights, heating, or less obvious items, are networked and contain sensors and actuators, provide a wide range of opportunities and questions for research. For example, perceptions of how the data created by these devices should be appropriately shared, both within and outside the home, are explored in Coughlan et al. (2013a). The kitchen is an area of particular significance, and has long been a space where new technologies have impacted on home life. Comber and Ploetz (2013) provide an overview of several projects from the 'Ambient Kitchen'. These include novel persuasive probes such as BinCam, which posts images of disposed items to social media platforms, creating a record for shared reflection on waste practices in the home.

3.2 Automation

Another part of these visions of the future home is an expectation that more of our routine tasks will be automated, being performed by robots or smart home systems.

Work, such as that by Lee, Sabanovic and Hakken (2013), explores how these types of technologies need to be designed with an understanding of the social dynamics of the home, eliciting issues such as how a robot might address an adult in front of their children. Home automation needs to be designed with an understanding of the practices that are actually valued. For example, Hoonhout (2013) introduces automation through installing novel appliances that take over tasks previously performed by household members, thereby disrupting currently performed activities and gaining understanding of what was liked or disliked about routine domestic tasks. Alternatively, Mennicken and Huang (2013) study households already living with home automation technologies, and their methods are designed to capture good and bad experiences of these early adopters.

New modalities of interaction suited to the home are also a key area in connection with automation and ambient technologies. Schlögl, Chollet, Garschall, Tscheligi and Legouverneur (2013) explore the potential for Voice User Interfaces (VUI) to interact with home-based services. Unlike other interfaces, the construction of VUIs mainly depends on domain-specific natural interaction data (i.e. variances of spoken input and dialogue behaviour). While a button-click can be interpreted as a clearly defined signal to initiate an associated action, spoken commands are often highly ambiguous. For example, if a voice-operated calendar application asks for the ending of an appointment, the user might respond with an exact time (e.g. “at 12pm"), with an approximation (e.g. “around noon"), or maybe provide a duration (e.g. “it will last for 2 hours"). The designer needs to define a set of possible responses leading to an appropriate dialogue model. Examples for potential applications in the home range from voice-operated entertainment technology (Möller et al., 2004) to ambient assisted living environments (Schlögl, Chollet, Garschall, Tscheligi and Legouverneur, 2013).

3.3 Energy and behaviour change

Energy studies are emerging as increasingly interdisciplinary domain for domestic research (e.g. Leder Mackley, Mitchell, Pink, Escobar-Tello and Bhamra, 2013; Mallaband, Haines and Mitchell, 2013). Digital technologies are used here both as means of recording, tracing and tracking energy use and as possible solutions for key problem spaces in this area, such as energy demand reduction and load shifting. Besides the technological and ethical challenges that underlie comprehensive energy monitoring in the home, we identify some key tensions between various notions of ‘behaviour change’ and the aim to facilitate everyday activities in a more sustainable

way. Linked to these tensions is also the spectrum from users' interactive engagement with technologies through to the creation of automated systems.

3.4 Assistance and aging

Technology for the maintenance of independent living in an aging population constitutes a further growing area of domestic research. In this space, researchers are looking to develop methods that help them understand and effectively engage with particular user groups in research and in design processes. Advances in networking and technologies embedded in the home could enhance the potential for telecare (e.g. Hine and Arnott, 2013), or reminder systems (McGee-Lennon, Williamson and Wolters, 2013). Research in this and other domains also needs to be mindful of including non-traditional home spaces, such as independent living communities (Brewer, 2013).

4. Augmenting Research with Technology

New technologies are not only an object of study in the home, they are often capable of augmenting traditional methods of data collection for research. This can be particularly appropriate for the home context if methods are combined to both relieve intrusion and aid understanding. For example, Yang and Newman (2013) analysed three sources of data in investigating the use of a smart thermostat: the 'Energy History' data generated by the thermostat itself, daily diary entries collected using a mobile app or website, and traditional interviews. The log data is a starting point for obtaining richer contextualized explanations of the events occurring in the home, while a mobile / online system for diary studies supports easier creation, collation and analysis of entries. Another example is the large-scale capture of data from homes through systems such as energy or water monitors (Erickson et al., 2012). These types of big data are expected to support organisational decision-making, but there is also a role for combining qualitative understanding of context along with this.

Martindale, Evans, Coughlan and Reeves (2013) describe how novel methods could allow greater understanding of how media is consumed in the modern, screen- and computer-rich household. In this case new technologies for network data logging and automatic video recording expand data collection possibilities in ways that enable interdisciplinary research questions to be addressed. Cultural relationships revolving

around television as technology and content are a longstanding area of social science research interest, just as user interactions with domestic devices are an established aspect of HCI. Given the increasing complexity of device ecologies and transmedia content functioning in the context of the home, new technologies necessitate a combination of disciplinary approaches and also provide the means to facilitate such research.

5. Representations of the Home

Across a range of research projects, there is a need to define and create representations of the home that facilitate data collection and discussion. In particular, these may represent physical and temporal aspects, which may augment understanding of what has happened in the home, or exploration of what could happen in the future.

Visual depictions of the physical space in the home, such as floor plans or sketches created by study participants, are used across research projects with diverse goals such as understanding energy use, home automation, or the design of domestic robots. These can be a means to plot routines or identify important technological features in the house. The value of such representations may be to provoke recollections about the routine activities and social dynamics that are essential in understanding the home, to aid in initial 'getting to know you' activities and to create a research space that is owned and shared by both participants and researchers (Leder Mackley, Mitchell, Pink, Escobar-Tello and Bhamra, 2013; Lee, Sabanovic and Hakken,. 2013; Mennicken and Huang, 2013).

5.1 Using a timeline to represent changes in the home

When researching the home as a system it is useful to find a way of presenting the way it was has changed over time, including changes made and external influences. An example of when this type of representation has been needed in practice was when researching home improvements that have been carried out in the home, as illustrated in Figure 1. This work (Haines, Mitchell and Mallaband, 2012) aimed to find out not only the home improvements that had been carried out in the home, but what motivated these improvements and anything that posed as a barrier to further improvements. For this study, a timelines tool was developed with the use of magnetic boards and a

bespoke set of magnets. Participants were encouraged to discuss changes made to the house along with notable events such a marriages, deaths etc. This information helped to build up a visual representation of the participants' time in the house and demonstrated the relationships between life events and home improvements, whilst also collecting information such as the amount of disruption and the cost of such changes. This type of activity is particularly good for engaging users and encouraging them to remember activities and details that have taken place; it could be easily adapted and used in a variety of fields.



Figure 1: Timeline tool used to discuss household changes with participants

5.2 A Dolls' House - engaging with stakeholders

Care is a dialogue between a patient/client and carers (Katz, Conant, Inui, Baron and Bor, 2000); this dialogue depends on information about the condition causing the need for care. One approach to gathering information is to record and model the lives of domestic residents as they live in their home, with the aim of detecting change in activity that could be correlated to changes in well-being. Such information would then be used to inform residents and carers about what is happening in the lives of the residents and help support the dialogue (the "dialogue of care") between residents and carers (Gil et al. 2007; Gil, Hine and Arnott, 2008).

A dolls' house has been built as a sensored space that mirrors a plausible telecare-equipped dwelling, see Figure 2. A variety of sensors have been installed to detect movement of dolls around the house, occupancy of seats and beds, use of wardrobes and cupboards, use of appliances and storage spaces in the kitchen, and interaction with fittings. The house gives an enjoyable way of engaging stakeholders in dialogue and discussion about domestic life. It relates directly to real life as it is a physical model of a normal house with technology installed. It is thus easy to understand and helps people who are less familiar with new technology to learn about technology in home care and discuss it with carers and other professionals. Direct physical interaction with

the house and its dolls makes it possible for people to work through domestic scenarios while discussing them. The house can be used as an alternative to computer-based simulations and visualizations of the home, which offer a virtual experience rather than a physical one.

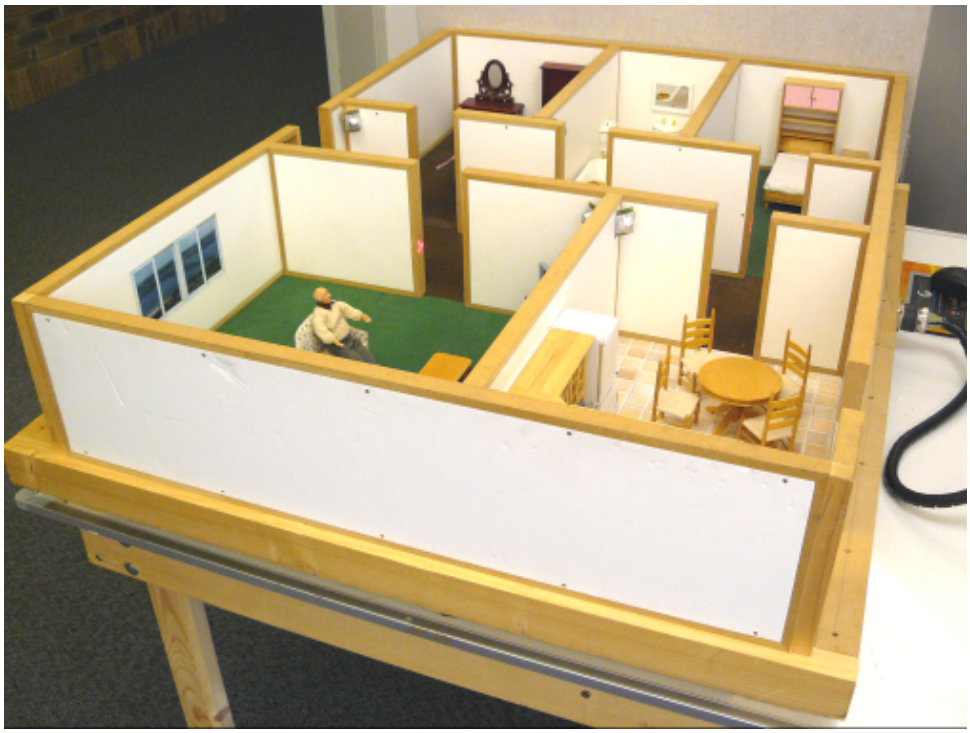


Figure 2: The Dolls' House. There is no roof on the house so that people can interact directly with items in the house, e.g. to open or close cupboard doors or move dolls around.

The sensors allow various normal activities and behaviours in the house to be enacted and recorded, including behaviours associated with sleeping, eating, personal hygiene and relaxation. Stakeholders playing out representative scenarios using the house and its dolls can provide data, gathered from the sensors in the house, to assist in the study of home care and the development and evaluation of new home care systems. Together with professional carers of older people, various scenarios (e.g. getting up and starting the day, leaving the house, having lunch) have been constructed. Data can be collected for later analysis and modelling. A database of simulated data is proposed, into which real-life modulations, anomalies and errors could be introduced, giving a resource for the investigation and trialling of data mining and business intelligence tools as analysis tools for this application context.

5.3 The sensory home

In recent years, theories of place from phenomenological anthropology (e.g. Ingold, 2008) and human geography (Massey, 2005) have inspired reconceptualisations of the

home as ever shifting multisensory environment (Pink and Leder Mackley, 2012; Leder Mackley, Mitchell, Pink, Escobar-Tello and Bhamra, 2013). Understanding the home not as a fixed structure or locality, but as unbounded 'entanglement' (Ingold, 2008) or 'constellation of processes' (Massey, 2005), allows researchers to follow and explore the intersections of both the material (people, objects…) and immaterial (air, sound, Wi-Fi…) 'flows' that constitute home. This conceptualisation, in turn, has implications for the methods that most readily access domestic movements and flows. Engaging research participants in re-enactments, for instance, or following them through the home as they go about everyday activities can provide important insights into domestic life, accounting for the kinds of tacit, embodied, experiential and situated knowledge that is difficult to gauge through interview methods alone.

On the LEEDR project, the concept of the 'sensory home' provided an indirect route to studying how energy use is implicated in everyday activities of maintaining the 'sensory aesthetic' (Pink, 2004) of home. Guiding both fieldwork and analytic processes, it disclosed the home as an on-going project, both in terms of decorative and structural changes and in relation to more mundane everyday activities of 'making home', such as cleaning, doing the laundry, engaging digital media, and negotiating flows of air (Pink and Leder Mackley, 2012).

In applying concepts such as embodiment, where mind and body are not considered as distinct in human experience, researchers can draw conclusions about changes in household life by analysing changes in physical activities at home. In particular, choreographies of movement found in the home environment can be explored and provide an important source of information (Pirhonen, Parviainen and Tuuri, 2013).

6. Representations of the Future

As with other application domains, guiding the design of future technology in the home requires the collection of early and on-going feedback. Here researchers and designers face the challenge of evaluating design ideas and products which are often only a vision of the future, and not necessarily represented by any existing product or easily prototyped to their fullest extent. While we might not speak of standardized process for gathering feedback for potential future services and products, one may identify a set of methods and techniques that can be used to support understanding of

a given design space. Here we discuss techniques that are commonly applied for considering future designs of technology for the home.

6.1 Scenarios and personas

A scenario is ‘a story about the use of the designed product' (Caroll, 2002). It represents an example of how a new technology might be used. A scenario is a narrative description of a discrete use case. As such it needs to be salient as well as realistic and is iteratively refined throughout the development process. Scenarios include the context of use, the person using the product, the goal that is to be achieved, a description of the task, possible external events influencing the product behaviour, as well as the outcome for the user. There are similarities with the use of vignettes to elicit responses in social science research, but scenarios aim to support design as well as represent potential designs to users, providing a dynamic representation of how a future product might work in context.

A persona is an archetypical representative of an actual group of users and their needs (Cooper, 2004). In contrast to potential users identified by market segmentation, a persona is not based on an individual person, customer segment, demographic data or a job description. Rather, it is a representative exemplar of a person with associated sets of behaviour and motivations. Personas provide designers with a person for whom a product is being designed, and help them to consider their experiential needs. Given the importance of social interaction in the home setting, it should be essential that multiple personas are built, based on different household members, and incorporating their distinct characteristics and (often conflicting) interests.

Within the home setting, there is a particular difficulty in applying scenarios and personas in a meaningful way, such that they are appropriate for a range of users and reflect their home relationships and context. A method developed in response to this is to present ‘Tailored Scenarios’, where a generic scenario template becomes contextualised through tailoring it to the individual user’s household members, generating a narrative of what might occur when a new technology is introduced to the home that actually includes each participant’s own household (Coughlan et al., 2013a). Another method found to be useful in the early stages of design is ‘Rich Use Scenarios’. This focuses on having sufficient richness in the creation of the scenario, such that the designer can identify with the user effectively (Pirhonen and Murphy, 2008).

6.2 Prototyping

Prototypes serve the purpose of eliciting user feedback on design decisions. On the one hand there are low-fidelity methods such as sketching and storyboarding (Kieffer, Coyette and Vanderdonckt, 2010), which are mainly used to evaluate early concepts and design ideas. On the other hand, more realistic feedback may be collected through high-fidelity artefacts, where mock-ups are used to evaluate the physical form of a product and prototypes are employed to learn about the quality of its envisioned functionality. While the creation of prototypes may be an effective instrument for feedback elicitation, the accompanying costs - both of developing the prototype and of effectively studying its use in a home context, or an analogue of this - are often high. Ogonowski, Ley, Hess, Wan and Wulf (2013) found frustration amongst Living Lab participants that technologies installed in their homes did not always work as intended – almost an inevitability when prototyping. It is difficult to strike a balance between testing novel ideas, and interfering in the valued time spent relaxing in the home space. Equally, compromises are often necessary in simulating technologies requiring extensive infrastructure that does not currently exist (e.g. advanced smart home automation, or systems that interact with envisioned future services in the wider world). As such, there is a large amount of work to be done in successfully designing these studies, and in overcoming barriers to envisioning the future.

Wizard of OZ (WOZ) is a prototyping method widely used by researchers and designers to obtain early feedback on features that would otherwise require significant resources to be implemented. Voice user interfaces can be seen as one representative of this type of applications. Others may include augmented technology artefacts (Hemmeryckx-Deleersnijder and Thorne, 2008) or ambient living environments (Li and Bonner 2013). In this a human ‘wizard' simulates the functions of a potential future system, either entirely or in part, which allows for the evaluation of user experiences and interaction strategies without the need for building a fully functional product first (Kelley, 1983). WOZ has also been used as an instrument for collecting various types of corpus data. This data is required to support the design of Voice User Interfaces and intelligent Spoken Dialog Systems, technologies that are increasingly used in the home context. More broadly, the use of WOZ in the home raises interesting issues around privacy, trust, and the roles taken by researchers.

A further approach to prototyping, which aims to be mindful of the importance of rich social and contextual aspects of our experiences of technology, but also of the costs of developing fully working technologies, is User Enactments (Odom et al., 2012). This

entails participants taking part in short, embodied enactments of situations, with novel design concepts included through lo-fi prototypes. These can be conducted in real homes, for example in one case study exploring the design space of teenagers' bedrooms. Equally, mocked up home environments have been used as a space in which to conduct these enactments.

6.3 Probes and disruption

A particularly interesting aspect of physical prototypes in the home context is their potential for exploring user interactions with the 'unknown', sometimes unpredictable and disrupting artefacts, which might provoke interesting insights or behavioural change. An early example may be found in Gaver et al.'s 'Illuminating Tablecloth' (2006), which triggered experimentation and interpretation, and eventually led to new routines. Probes are a particularly useful approach both to design and to gaining a better understanding of routine behaviour. Various forms and uses of probes have continued to be explored in researching the home, with Gaver et al. (2013) deploying a series of probe designs than sensed and represented the environmental conditions inside 20 households. The focus of these probes is playful rather than utilitarian, provoking thought rather than representing a design with a clear use. Hoonhout (2013) utilises the probe method in the kitchen by introducing a system that automates routine tasks, while Bourgeois, van der Linden, Price and Kortuem (2013) installed displays that made visible new forms of information about the renewable energy being silently generated in homes with solar panels.

Users do many daily activities in the home in a routine or more or less 'mindless' way – daily food preparation is an example. When interviewing users about such everyday routine activities, it often turns out to be hard for them to express what the most important elements and drivers are in carrying out such activities. Regarding food, it is likely that participants will tell you for example that time, health and taste is important, but certain routine elements in the actual preparation of the food that are also important to them might not come to their mind so easily. By letting people work with probes or prototypes that disrupt their usual way of working, they can come to realise what these drivers are. Of course, disrupting everyday routines has some ethical implications, but for participants it might also be enlightening to realise what they value in routine activities, and to share these experiences with the researchers. Disruptive probes seem thus to be a possible way to unsettle participants, upset their routines and thus help them to realise what they like and dislike about these routines, what elements in

these habits are in fact really dear to them, even though they were not consciously aware of that before.

7. Conceptualisation of People

People are often conceptualised as at once resources and stumbling blocks in the study of technology in the home. How we make sense of participants - whether primarily as psychological or social beings, as embodied, discursive, reflective, habitual, active or restricted - impacts on all stages of investigation. In many ways, this is the nature of social research. Building on what has been discussed in the prior sections, the study of people and technologies in the domestic sphere brings with it specific challenges and opportunities, not least because people's domestic identities and activities have traditionally remained 'hidden', both for reasons of privacy and because many routine aspects of domestic life have appeared too ordinary to warrant further exploration (or are, indeed, difficult to track or trace). Our research community has identified a range of shared and divergent understandings of people in the home, exploring theoretical and practical implications in the process.

Researchers are addressing a variety of households and occupancy constellations, including family homes (Leder Mackley, Mitchell, Pink, Escobar-Tello and Bhamra, 2013), single-occupancy houses (partly with older inhabitants), and independent living communities (Brewer, 2013). For research projects that employ sensor technologies, the varied nature of occupancy can be a practical challenge, not least when it comes to identifying and tracking individuals' movements and activities. Even in single-occupant households, there are instances when spaces are shared, if only intermittently, for example by visitors or carers. Beyond this, on a theoretical and conceptual level, research on technology in the home needs to reflect on whether to engage with people as individual or social beings, or indeed if there are moments when individual and social experience can be meaningfully intertwined. Psychological models of attitudes and behaviour often stand in contrast here to sociologically and anthropologically informed work that either focuses on the practices that participants partake in or considers the dynamics of social interaction. There are related tensions between conceiving of participants as individuals with inherent motivations and underlying drives (which, it is assumed, can be measured, exposed and engaged) and as social and

discursive subjects whose experiences and activities are contingent, embodied and emplaced.

In this context, a recurrent theme amongst researchers is the desire to get as close as possible to what are described as 'truthful' depictions and representations of people and domestic life. Whether relating to the accuracy of participant recall or the elimination of 'noise' from monitoring data, the balance between documenting and interpreting everyday domestic life seems difficult to strike, not least in the context of interdisciplinary research. While epistemological foundations may vary amongst researchers and, indeed, the very notion of truth is problematic for some, there is consensus that studies of the home need to account for people's experiences and activities as complex, meaningful and multi-layered.

An initial working distinction can be made between habitual and reflective modes of experience and engagement, both in the context of data collection and the design of future technologies. While the notion of 'embodiment' has problematised crude body/mind distinctions, rendering the body itself as a source of 'knowledge' (Pink 2009), accounting for the range of people's sensory-embodied, tacit and cognitive-intellectual meaning-making processes is not simply a question of oppositions but, increasingly, one of finding multiple routes into the study of everyday domestic life. This is not a call for 'anything goes' research but for increased researcher reflectivity as to the kinds and layers of human experience that methods can reveal and that design can respond to.

7.1 Abstract notions of people

As the use of personas in design processes exemplifies, there are also a range of more abstract(ed) ways through which to make sense of, or imagine, participants in and as part of domestic environments. Using dolls as 'stand-ins' is one such example that illustrates research possibilities for potentially sensitive domestic settings. Likewise, collaborative design techniques often involve participants to imagine kinds of people or ideal technologies (e.g. Lee, Sabanovic and Hakken, 2013). Beyond this, theories of place, as described above, conceptualise both people and objects as 'things' that intersect or 'correspond' (Ingold, 2013) at different intensities as part of, rather than separate from, domestic environments as 'places' (cf. Pink and Leder Mackley, 2012). Or else they can be part of choreographies of movement that bring with them their own logic of domestic life and experience (cf. Pirhonen, Parviainen and Tuuri, 2013). Importantly, any abstraction of people has to be seen as just that - a

methodological tool or route to knowledge - which cannot or should not replace researchers' engagement with 'real' people in 'real' settings.

8. Conclusions

Although there is a significant history of research around the home, there are recent technological innovations and pertinent foci that require current reflection and attention. The home will never be an easy context to study, but with regard to technology it has grown to be an essential one. It is also important to note that many projects studying the home adopt multiple methods, and also consist of cross-disciplinary teams, for example including technical, design and social science expertise. Leveraging all these skills is part of an effective approach, as a project may for example require the installation and capture of data via technology, the understanding of human behaviour, and the need to create and evaluate designs.

As new technologies provide ever-greater potential to collect forms of quantitative data from our homes, we must expect further focus on the means to ethically and efficiently achieve understanding of activities such as energy or media consumption. At the same time, context is required to understand this data, and there is a need for innovation in combining this data with qualitative understanding of the richness and individuality of our experiences and interactions in our homes.

A theme running through many of the projects and methods discussed here is the complexity of the relationship between researcher and participant. In allowing researchers to enter the home, or in sharing data beyond the walls, participants place significant trust in researchers, so these relationships often require more work and care than normally found in other situations. In addition, many methods work to bridge the gap between what the researcher might miss when they look at domestic spaces through their own, unfamiliar eyes, or what the participant might forget to mention due to over-familiarity: such as the history, the relationships, and meaningful routines or objects. Representations that the participant and researcher create together therefore become necessary 'boundary objects' (Star and Griesemer, 1989) as we develop our shared understanding.

Discussions amongst a community of people working in the area provided an excellent opportunity to map out the current space of approaches in studying the home, and to identify the challenges that are repeatedly found across diverse research projects. It is also valuable to see trends in the types of questions research in the home is tackling, and how technology is playing a role itself in the capture of data and support

for analysis. As a result, this paper captures our shared understandings of the state of the art in this area.

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