

# Researching Privacy in Smart Homes: A Roadmap of Future Directions and Research Methods

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## Abstract

The adoption of smart devices in homes is rapidly advancing, and information on our daily routines and activities is collected, processed, disseminated by these devices in order to function. People have specific ideas as to which, when, why, and how information on them may be collected and used. They feel infringed in their privacy if data collection practices deviate. To address this issue, we suggest a roadmap of future directions and research methods for privacy research on smart homes. We systematically review privacy-related papers to identify research gaps, reflect on methodological choices, and propose research designs to fill these gaps. Our key conclusion is that privacy research in Smart Homes needs to be holistic and contextual.

## 1 Introduction

The smart home market is forecasted to grow to \$40.9B by 2020. Internet-connected devices in the home span a variety of application areas, are increasingly unobtrusive, continuously collect data, and are carried across physical borders. People express “resistance, bewilderment, and sometimes resignation” [1] as they learn how data around and about them is collected and subsequently used. This situation is commonly referred to as an infringement of privacy. Smart homes, as part of the internet of things, have the potential to exaggerate these issues as our homes are traditionally perceived as one of the most private spaces, and yet becoming increasingly equipped with ambient technology.

The concept of smart homes is currently evolving from its roots in home automation to a wider definition which is inclusive of any internet-connected device. While existing studies of the internet of things focus on security and optimisation, less attention has been paid to privacy in the smart home. Privacy research itself has now turned towards the internet of things, but many challenges hamper the debate. More research on social, cultural, and technical factors is needed to fully explore the issues of privacy. A better understanding of privacy in the home will inform improvements of policy and product development. We postulate that with a rigorous understanding of the smart home privacy context, we will be able to explain,

predict, and devise ways of minimising the feelings of “resistance, bewilderment, and sometimes resignation” [1].

In this paper, we analyse existing literature on and related to privacy in smart homes. The review reveals existing research gaps in the context of smart homes. In addition to a content-focussed review of these papers, we focus also on methodological considerations and their suitability in addressing specific research problems. We then use these insights to devise general recommendations of methodology usage for the identified research gaps. The resulting roadmap presents five steps which address the challenges of privacy research in smart homes.

First: the development of tools and devices which enable privacy research in smart homes by demonstrating data collection, processing, and dissemination in context. The aim here is to explore tools that can facilitate further research by collecting useful information, or provide in-situ contextual information to smart home users to understand, visualise, and act upon.

Second: an in-depth analysis of the smart home context, for which a pragmatist mixed-method approach seems best suited. This could be used to understand smart technology usage as part of daily routines and to elicit expected and perceived benefits, motivations, intentions, and challenges. We suggest applying an inductive approach for data analysis, grounding theory in data.

Third: as shown in studies gathering empirical data on technology usage and privacy behaviour, understanding, preferences, and behaviour have been reported to change over time. We propose longitudinal panel studies which allow monitoring these aspects. The data can be used to inform a model of smart home privacy which in turn could relate to existing frameworks.

Fourth: addressing the perspective of policy makers by exploring the means of facilitating discussion about privacy issues. This can be based on a model of smart home privacy (e.g. as described in step 3) to guide and facilitate understanding and discussion. Also, existing regulation can be contested by engaging in discussion with privacy experts and policy makers in the UK. This discussion might take place in form of focus groups or by using the DELPHI method allowing participants to contribute remotely.

Fifth: addressing the criticism that existing frameworks for product design are too vague. Research should devise design principles that respect privacy in the home. Such investigations can be made in discussion groups with between designer, developers, and academics. Outcomes of these discussion can inspire further research and inform product development.

The rest of this paper is structured as follows: (2) presents a summary of our literature review and highlights research gaps; (3) reviews methodology in relation to existing contributions; and (4) links the literature gaps with a proposed methodology.

## 2 Research Context

This work is situated in the wider context of research on privacy and the internet of things. To explore existing research, an initial literature review applying hermeneutics as methodology was conducted. The hermeneutic circle as proposed by Boell and Cecez-Kecmanovic [2] allows the researcher to refine his own understanding while iteratively searching, acquiring, and analysing relevant literature. After five iterations focussing on privacy (1x), the privacy paradox (2x), and smart homes (2x), the literature review included 60 papers. Because smart technology in the home is an emerging topic with sparse literature focussing on privacy, we also covered other technological areas that have drawn the attention of the privacy research community in the past (see Figure 1).

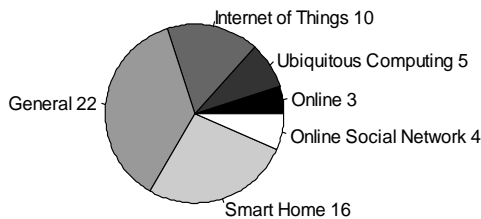


Figure 1: Technology focus of reviewed privacy literature

### 2.1 Privacy

Warren and Brandeis published their seminal work “The right to privacy” in reaction to “political, social, and economic changes” and formulated “the right to be let alone” [3]. Westin expanded on their work and described the idea of informational privacy [4]. Altman expanded on Westin’s idea to include a contextual notion which explained why individuals at times seek privacy and at other times disclose information [5]. Altman understood privacy as a social process which involves interaction with the social world and the environment. Expanding on the social aspects of privacy, Nissenbaum proposed the concept of Contextual Integrity which emphasizes the importance of context: “structured social settings characterized by canonical activities, roles, relationships, power structures, norms, and internal values (goals, ends, purposes)” [1, p. 132]. Contributions from legal scholar Lessig pointed towards economic impacts on privacy as the internet enabled trading information as a good. In summary, privacy incorporates inherent human needs, was shaped by society over time, and should be contextualised whenever assessed.

Often referred to as the privacy paradox, there has been an observed dichotomy between users’ privacy attitudes and their behaviour which was first reported by Westin when he asked interview participants about their privacy preferences [4]. Exploring this phenomenon, researchers from different disciplines made contributions to the field and others have summarized their work in literature reviews. To inform public policy, some authors highlight the uncertainty of users, the malleability or influence exercised by data holders, and the context-dependency of privacy as such [6]. Calling for a synthetic model of privacy behaviour, Kokolakis reviewed the fields of privacy calculus, social theory, cognitive biases and heuristics, bounded rationality, incomplete information, and information asymmetries [7]. Barth and de Jong focussed on challenges related to mobile computing [8] arguing that the nature of mobile computing requires faster decision-making which makes the paradox more complex. Closest to the smart home context is the review of Aleisa and Renaud [9], based on Ziegeldorf et al. [10]. Their understanding of privacy is based on Westin’s categories, and they disregarded context-dependency in privacy decision-making. Smith et al. [11] argued for positive empirical tests of actual outcomes of privacy behaviour and to attempt an overarching, context-neutral framework.

Some researchers argue that the privacy paradox does not exist because attitudes are generic whereas behaviour is specific [12], or users surrender in the face of a superior industry [13, 14]. An argument based on purely rational behaviour of users advocated privacy calculus and was soon enhanced to include biases and heuristics turning towards the field of behavioural economics [15]. Focussing on psychological explanations, researchers applied the Theory of Planned Behaviour and have claimed to have solved the paradox [16]. Other researchers turned towards social theory to explain sharing behaviour through group pressure [17] or challenges in decision making caused by a lack of a social representation [18].

In a vignette study, Naeini et al. surveyed 1007 participants to find out that people preferred data collection in public rather than private places. They preferred collection of data for their benefit, were less comfortable with biometric information being collected than environmental data, and they wanted to be notified of the usage of data [19]. Considering existing practices (without using technology) and norms for information usage, these findings appeared largely intuitive. In fact, Nissenbaum’s theory of Contextual-Integrity argues for a consideration of information flow in context. According to this theory, context is understood as “structured social settings characterized by canonical activities, roles, relationships, power structures, norms (or rules), and internal values (goals, ends, purposes)” [1, p. 132]. Barkhuus [20] illustrated how the theory of contextual integrity could be used to explain user behaviour and therefore asked for a more nuanced investigation of privacy which focussed less on trying to measure concern. Barkhuus postulated that using different vocabulary might help to further dissect the problem, that investigating attitudes and concerns, and speaking about “privacy” blurs the discussion. Martin and Nissenbaum [21] showed how considering context – cofounding variables – was

better suited to explaining privacy preferences, as information sensitivity and concerns appear unstable without considering context [21].

We conclude that privacy is constantly evolving over time, influenced by societal changes, technological advances, and situated between the poles of economic and regulatory influences. It appears that regardless of the paradox's existence and its plausibility, privacy decision-making remains challenging. Users must be supported in taking adequate decisions. Hence, research has to consider heuristics and biases that influence decision making. More importantly, privacy has to be considered in context, for example applying Nissenbaum's theory of contextual integrity. Carefully exploring context, the framework's descriptive approach appears promising in disentangling what is understood by privacy in (smart) homes, describing situations in which people feel infringed in their privacy.

## 2.2 Smart Homes and Cohabitation

Because new technologies and their use in the home is continuously evolving, attempting a strict definition of smart homes may be more limiting than beneficial. Thus, we understand smart homes as "residences equipped with computing and information technology which anticipate and respond to the needs of the occupant" [22]. Functionality of smart home technology spans the categories of entertainment, energy management, security management, health/home care, communication, controlling appliances, and increasing comfort levels [23]. It is common for devices to fall in more than one of these categories, making it rather difficult to provide a distinct taxonomy. As the authors of [24] highlight, the technological landscape in the home is messy, with several large competitors and no standardisation. This situation inevitably results in diverse topologies and bears the risk of vendor-lock-in for consumers [25]. For the purpose of this paper, smart home technology is described sufficiently as a set of sensors (data collection), actuators (performing actions, e.g. light switch or speaker), and smart objects which include them. Smart objects can be anything along the lines of smart bathroom scales, IP cameras, and home automation systems for building infrastructure. Central to each smart home set up is a hub with which smart objects communicate. Depending on the architecture chosen by the manufacturer, the hub might be connected to a cloud service where data may be processed and stored.

Researchers investigated the home as a social and functional space. For example, an ethnographic study [26] analysed the daily life of dual income families. According to these findings, the house was perceived as more than just a location, fulfilling multiple purposes and ultimately contributing to the construction of family identity [26]. Other ethnographers specifically focus on the nature of communication of household members and find possibilities for future design and integration of devices into the household [27]. One of the two authors investigates how – that is where, in which context, with what purpose, and how often – things are used in the home. These findings suggest that the use of "things" could not be

seen isolated as they are often part of an "assemblage" rather than fulfilling a purpose on their own [28]. Less literature explicitly addresses the smart home, that is the usage of smart technology and effects thereof on cohabitation. The authors of [29] discuss how digital technologies changed the order of the home, conflicting with what was seen as "appropriate behaviour". Closer to our understanding of the smart home context is the work of Brush et al. who focus on home automation systems (building management). Their findings highlight usage challenges and possible improvements. Other usability studies include [30, 31] who asked their participants to keep a device in their home while they studied perceived benefits and concerns. They reported trust as a critical factor for adoption [31] and also reported privacy concerns [30]. Zeng et al. [32] conducted 15 semi-structured interviews with smart home administrators and users, exploring attitudes, expectations, and actions. They found that physical security was perceived more important than privacy. They also highlighted a mismatch between knowledge of primary users and other users in the same household, and noticed that users were trading off security and privacy versus cost and interoperability when making choices [32].

## 2.3 Summary

We have reviewed relevant literature on privacy, smart technology, and the home, and have identified the following research gaps.

- Contributions to privacy almost exclusively consider individual privacy; cohabitation requires us to consider also group privacy, for example as highlighted by Smith et al. [11]
- Development of "privacy" over time – most contributions only provide point in time accounts of privacy preferences; monitoring privacy behaviour and usability over time is an important consideration
- Privacy *behaviour* is under-researched – most contributions report on privacy attitudes rather than actual privacy behaviour
- Privacy has been researched in different contexts, e.g. Information Systems research on internet applications – some authors propose to research a macro model that spans different contexts, e.g. [11]
- The smart home context – Insights (motivation, perceived benefits/challenges) into usage (habitual or routine) of smart objects in the home considering different forms of cohabitation and blurred contextual borders through technology usage in the home
- Privacy in the smart home – only few contributions have been made investigating privacy in context of the smart home

## 3 Research Paradigms and Design

The aforementioned research gaps naturally span various disciplines and addressing them potentially involves applying

a variety of different methods. This section briefly reviews methodological approaches, relates them to the reviewed *privacy* literature, and discusses their suitability for future research.

Remarkable in its absence when reviewing existing literature has been any discussion of ontology and epistemology in methodology sections. In the social sciences, similarly in other disciplines, ontological and epistemological discussions are long standing debates [33]. We believe that due to the nature of the research challenges and in particular because privacy has to be understood in context, social science methods offer promising tools in disentangling the state of privacy in context of smart homes. The following provides a discussion of ontology and epistemology with respect to the nature of privacy and highlights resulting benefits and limitations with regards to possible research methods. Handbooks of social science enquiry highlight the benefit for a researcher in learning about the plurality of different philosophical stances that are available to guide their research [34, 35] – “mindfulness of the contours of one’s own philosophical assumptions and mental models makes for better social enquiry” [3, p. 7].

### 3.1 Positivism and Constructivism

Without explicitly stating it, existing approaches have denied traditional research paradigms such as positivism on the one hand and realism or constructivism on the other hand. The following provides one possible argument in two steps. The first part of the argument is based on observations of the nature of inquiry into privacy. The second part considers the practicality of research methods.

As aforementioned, many studies have found evidence of a dichotomy between attitude and behaviour: the so-called privacy paradox. The paradox’s emergence in academic literature and the many attempts to solve it, challenge the suitability of a strictly positivist paradigm – positivist ontology assumes that there is a single objective reality which research has to discover through empirical research, following the idea of experiments in the natural sciences and independently of the researchers perspective and beliefs [36]. The main criterion here is not whether a study highlighting the paradox exhibits a positivist stance, the point is that the nature of inquiry, e.g. questions being asked, necessarily required us to consider the context in which they were asked which includes the role and knowledge of the researcher. Furthermore, privacy is an issue inherent to and resulting from interaction between humans. In research, the enquirer’s position and knowledge, among other aspects, necessarily has to be considered when analysing data. A positivist position would deny such considerations.

The inherently interhuman nature of privacy hence seems to be in favour of a constructivist philosophical stance – constructivism assumes that the world is constructed through our beliefs and knowledge, therefore only subjective truth exists [37]. If we were to approach privacy research this way, issues of practicality were likely to arise. Privacy has already been manifested in law, stretching its application across diverse populations such as the EU. Subscribing to a purely

constructivist world view might limit applicable methods to interpretative enquiries [33]. This might be disadvantageous if the researcher intends to test the generalisability of findings through quantitative methods, e.g. to inform related fields of practice or research. Though this might be less of an issue in situations where quantitative methods are to increase the validity and reliability of findings rather than attempting generalisation. However, as constructivism is naturally close to qualitative methods and positivism closer to quantitative methods, the philosophical discussion might rather hamper research than provide a framework that facilitates good research.

### 3.2 Pragmatism and Dialectics

Acknowledging the existence of many more philosophical stances, we turn our discussion here to more practical methodological solutions. Two such approaches which offer interesting insights and avoid the debate and necessary decision to choose either of the aforementioned extrema (positivist versus realist) are pragmatism and dialectics.

Following Biesta [34], Dewey’s pragmatism offers an interesting set of philosophical tools rather than a philosophical school of its own. As Biesta stated, these tools can prove useful in overcoming the debate which often separates qualitative and quantitative research. According to Dewey, knowledge comes about through interactions (transactions) of individuals with their environment (including other individuals). These transactions involve actions and consequences. We learn by establishing warranted assertions that based on our experience certain actions lead to certain consequences. Because the only way we can acquire knowledge is through transactions, pragmatism denies the possibility of non-interactionist research. Any observation, according to pragmatism, is an intervention with the environment. In creating knowledge (warranted assertions) research aims to either understand reasons and intentions for social action or to explain causes and correlation between events. Because knowledge in pragmatism is essentially knowing as a mode of experience which individuals learn from actions and consequences, a pragmatic approach is more suited for explanatory rather than interpretative approaches. Since knowledge is gained through interactions with the environment, it is subjective and by definition cannot be objective. However, an intersubjective world is created through interaction, cooperation, coordination, and communication which overcomes the issues of having to judge whether knowledge (the occurrence of experience) is subjective or objective [34].

Dialectics embraces the multitude of different stances (including pragmatism) based on the assumption that complex human phenomena can be best understood considering insights from different perspectives [35]. As opposed to triangulation which seeks to provide congruent results for greater confidence, dialectics embraces contradictions and differences in outcomes to engage in an open discussion. Such differences might include aspects of different contexts that are being studied (e.g. culture, ethnicity, or religion). Consequently, the value of dialectic enquiry lies “in the construction or

composition of inferences, drawn from purposeful conversations among and integrations of different threads of data patterns” [4, p. 10].

Both approaches offer legitimate forms of enquiry for complex problems in the social sciences. Both approaches aim to provide warranted inferences. Whereas warranted inferences in dialectics are understood to be “more comprehensive and insightful understandings” of the problem [4, p. 28], pragmatist approaches favour actionable knowledge to improve the problem under investigation [35].

### 3.3 Review of Research Designs

The multitude of existing privacy research covers the breadth of available philosophical stances and research designs, often strongly interlinked with existing traditions in their respective disciplines. We briefly highlight methodological approaches representative of the papers we have reviewed, before we discuss further benefits which a thoughtful consideration of research designs and methods can offer to enquiry into privacy.

Contributions from psychometrics followed the classic methodological approach of the field and were naturally close to the ideas of (post) positivism and often start with (pre-existing) theories which were then tested for a phenomenon observed in privacy research. Researchers used quantitative studies to probe the applicability of such theory in this manner [16, 38, 39].

Researchers applied a set of social science methods as part of their research. Qualitative enquiries through interviews [40, 41] were used as means to elicit data for inductive coding. Researchers used focus groups and online discussion forums to flesh out a theory which was devised based on existing literature [13]. Inductive approaches in these contributions were, however, only loosely defined. One example for a quantitative contribution was the work of Martin and Nissenbaum which measured privacy in a well-informed context [21]. Other research leveraged mixed method approaches. Methodology literature highlighted a number of possible methodological combinations and the character of research they matched best [42]. The studies we reviewed applied explanatory approaches. Researchers used semi-structured interviews to elicit opinions and intentions to complement preceding surveys, e.g. [43]. The authors of mentioned research papers chose their methodology following the research problem. Other research questions might be better answered through other forms of mixed methods, e.g. exploratory research questions. In that case, quantitative enquiry would enrich data which was previously gathered through qualitative methods. Mixed methods can also be used to increase the generalisability of a qualitative study by sampling participants from a preceding quantitative study. Ultimately, a quantitative study could be used to test findings from a qualitative study [42]. Longitudinal studies offer another interesting route for monitoring change over time, either in a repeatedly qualitative fashion (e.g. interviews or diaries) or through quantitative data [44]. Among the studies we reviewed, three longitudinal panels monitored user privacy

behaviour online [45, 46] and the effects of surveillance in the home [47].

### 3.4 Design for Contextual Privacy Research

As we have established in our review of existing literature, investigations into privacy need to consider context to capture the full spectrum of aspects that influence privacy. Many existing contributions either made use of pre-existing theory from other disciplines (e.g. psychometrics) or devised theory conceptually before testing it out. Because privacy is inherently interhuman and has evolved alongside technology over time, inductive approaches based on collected data can provide valuable contributions to the field, e.g. grounded theory. We believe that following the idea of dialectics by considering further findings from larger scale surveys and through the consultation of existing literature, a richer understanding of privacy in context can be achieved. Privacy preferences have also been known to change over time, illustrated by, e.g., the term privacy salience. Longitudinal (panel) studies offer the potential to capture notions aspects and factors of privacy that change over time. If privacy research is to inform important areas of application, e.g. policy and economics, then a better understanding of privacy development is required. Different forms of interventionist research (e.g. action research or ethnography) [48] taken from social sciences offer interesting perspectives, far more flexible and richer in gathering information than non-interventionist approaches (e.g. surveys) [35].

We believe that social sciences offer a useful tool set to gather, analyse, and dissect such rich sets of data. In applying social science methods to research contexts, we emphasize the importance of being aware of the various methodological frameworks and mental models that exist. The dialectic approach offers the required flexibility to tackle the complex problem of privacy. It also facilitates further exploration through engaging in discussion where findings appear contradictory. We see the strength of pragmatism in applying a rich understanding of privacy in context to real world challenges. Bridging the gap from rich and deep theoretical understanding of privacy in context of smart homes pragmatism offers the framework to apply the gained knowledge to existing challenges of product design and public policy. One such approach appears to be Helen Nissenbaum’s framework of Contextual Integrity [1]. Because of its explanatory nature as to why and when individuals feel infringed in their privacy, it is well supported by the concept of pragmatism. This can be illustrated as follows. Rich data collection following a pragmatist approach requires the researcher to think in “transactions” that are sets of actions and resulting consequences in a specific context. Because contextual theories require to consider context in a similar way, this approach is beneficial in eliciting context factors (variables) and their significance to the problem at hand.

### 3.4 Summary

We posit that privacy research can benefit from thorough consideration of philosophical frameworks and the rich set of

available social science methods to foster the understanding of context in:

- Gathering rich data on the smart home context through qualitative explorations (e.g. interviews and focus groups); methods like grounded theory allow for rigorous analysis
- Monitoring behaviour and change over time through longitudinal studies, applying methods such as ethnography and action research while being aware of their methodological implications
- Exploring context from a dialectic stance in engaging with (contradictory) findings while respecting implications induced using a specific research design
- In researching privacy, being aware of normative assumptions as to which attitudes, concerns, behaviours, and outcomes are good respectively bad; e.g. by taking a pragmatist approach in applying the contextual frameworks

## 4 Research Roadmap

To address the challenges of privacy in the smart home, we have identified five areas for future research. We acknowledge that the research of privacy in the context of smart homes can be regarded as a somewhat limited view on privacy, in the tradition of prior information system privacy literature, e.g. [11]. These contributions argue that information system literature tends to limit itself to informational privacy, neglecting other interpretations of the concept and its importance to culture and society. However, we would like to counter this position. First privacy issues in smart homes are real-world issues requiring specific, pragmatic, and actionable solutions which we believe information systems research can deliver. For this kind of problem, we would like to emphasize the need for non-normative contributions—as also mentioned by [11]—which our roadmap predominantly suggests. Finally, the nature of the smart home is promising in that one can expect to find a concentrated account of attitudes and behaviours, useful to conjecture about similar contexts.

### 4.1 Researching Smart Home Technology

Better insights into technology and their manufacturers' practices can facilitate research and offers scenarios for end-user applications. For end-users, research has shown a power imbalance between administrators and simple users [32]. Research should deliver tools that allow for more transparency of data collection, processing, and dissemination practices of a smart home, considering specific configurations of their systems and allowing them to adjust settings according to their preferences. For researchers, tools that allow for the visualisation of data flows in context and demonstration of data processing practices would hugely benefit their work.

There are many challenges that have to be overcome to achieve this, one of which is the heterogeneity of the smart device landscape. Work by Sturgess et al. [24] abstracted device

functionality to capabilities, allowing the assessment of possible data collection given a set of devices. Future work could expand this model to visualize aspects of contextual integrity for demonstration purposes, e.g. one could include informational norms to the presentation layer (c.f. [1, p. 140]). Another challenge is the lack of standardisation for protocols, devices, and software development. Without standardisation, network topologies will continue to evolve and change freely. Proposals for standardisation are required for their adoption to be of benefit to consumers and manufacturers. As such standards are not to be expected, research needs to keep up-to-date with changes. Furthermore, it might be reasonable for researchers to create experimental smart devices, allowing them to integrate research support functions and to experiment with new ideas.

### 4.2 Using Smart Technology in the Home

In the same vein as prior inventions that have changed our lives, such as dishwashers or smartphones, current and future technology may impact the way we live. For the purpose of privacy research, it is of particular interest to understand how smart devices are used in the home, consciously as part of daily routines, habitual in our behaviour patterns, and entirely unconsciously as they surround us. Asking why, how, where, and when people interact with technology allows us to create more accurate profiles of technology usage.

As many smart homes devices provide new capabilities to the smart home, qualitative explorations are needed. Ethnography provide rich insights of single case studies can help us to elicit aspects of usability that should be considered, e.g. in the same vein as [28] that highlighted the importance of assemblages of things. These aspects can then be further explored in interviews and focus groups, covering broader group of participants. More information can be elicited from interviews, such as intentions, expected and perceived benefits or problems. Mixed method approaches are needed to test previously developed hypothesis or further enrich data to improve theory. We propose a constructivist inspired thinking – empathic interpretations [49] – in following pragmatist logic can support this (see discussion in 3.3).

### 4.3 Disentangling Privacy in Smart Homes

Existing contributions either theorize about privacy problems in the home or ask participants retrospectively about their preferences. At the same time, these contributions emphasize that privacy is contextual, and preferences can change over time – factors which need to be respected by future research.

Interesting approaches to research are available from social science methods. Keeping the balance of richness and transferability of findings, longitudinal studies need to be carefully designed and implemented. Promising are longitudinal, multi-cohort, prospective panel studies which monitor individuals or group of individuals overtime [44]. The specific implementation can vary between observational and interventional, the two options being not mutually exclusive. Towards the observational end, ethnography and participant

diaries are methods to gather rich, qualitative and quantitative data [50]. A collaborative, in-situ approach using action research can combine practical outcomes with new understanding [48]. Such studies need to be designed to include quantitative and qualitative aspects, that is they can be used to test and apply pre-existing theory while further advancing it. A resulting understanding of privacy in the smart home can be again tested using further quantitative methods which allow richer considerations of context, e.g. inspired by vignettes [51].

#### 4.4 Implications for Policy

Public policy is sometimes called the business end of political science and combines domain expertise with a broad variety of other skills [52]. In exercising control through policy and regulation, governments are often said to fail in keeping up with developments in the technology sector. At the same time citizens expect them to protect their interests and to rebalance the economical (financial and informational) imbalance between customers and service providers.

Research needs to challenge existing policy and regulation (e.g. the General Data Protection Regulation (GDPR)) with the goal to improve further research and orientation. To do this, policy experts and domain experts from cyber security need to come together. To facilitate discussion between these two groups, focus groups or the DELPHI methodology can be used. A thematic analysis of such a discussion needs to further inform commentary on existing regulation and propose improvements.

#### 4.5 Implications for Product Development

With GDPR, Privacy-by-Design becomes part of effective regulation in 2018. This direct link between public policy and product development poses new challenges for manufacturers in software design as part of their product development. Privacy by design, and similar frameworks, have previously been criticized for being too vague. Especially because GDPR also threatens severe fines in case of lacking compliance, research needs to deliver on both a better understanding of what is privacy as part of regulation (see 4.4) and how software design can meet the requirements posed by regulation.

In the same vein as improving policy, experts on software development frameworks and privacy researchers need to gather. A structured discussion in focus groups or using the DELPHI method needs to challenge existing frameworks while proposing improvements for future version.

### 5 Research Agenda

This research agenda details our own research intentions [53] in more detail, and illustrates how the roadmap can be used to guide further research. We approach privacy in the smart home from a socio-cultural perspective, holistically and based on a rigorous understanding of its context. For our own research we will apply a pragmatic approach, providing us to apply the methodology best suited for each part of our research (see discussion in 3.4).

#### 5.1 Researching Smart Home Technology

Although our own research could hugely benefit from tools to demonstrate and illustrate data flows, we have no intentions to focus our attention on such research efforts. We will either rely on cooperation with other researchers or will use simpler means of demonstration.

#### 5.2 Using Smart Technology in the Home

What is the context of smart technology usage in the home? In the style of structured social settings (activities; roles, relationships, and power structures; norms; and internal values such as goals, ends, and purposes) [1], we aim to provide a rich account of smart technology usage in the home including values, ends, and purposes which people perceive when using, and attribute to, the use of technology. Gathering rich and diverse information—which is at the same time representative—will be challenging. We limit the scope of our research geographically. By applying grounded theory, we will systematically analyse data from semi-structured interviews and plan to deepen emerging themes in focus groups [49]. Compared to a broader set of interview participants, focus groups will consist of a more homogeneous group. The model (theory) extracted from qualitative enquiry will be complemented and verified through a larger-scale quantitative survey. It is not our goal to achieve representativeness of the survey or generalisability of qualitative findings. Instead we focus on enriching and complementing the theory through open ended questions which can be linked to grounded theory.

As we neither strive to reach representativeness nor completeness, we suggest a pragmatic approach for this research, aiming for “warranted assertions” [35, p. 17] not universal truth in a positivist understanding. Being aware of context and assumption, the researcher should separate the normative from the descriptive, providing precise insights for future research. A constructivist inspired thinking – empathic interpretations [49] – in following pragmatist logic can support this (see discussion in 3.4).

#### 5.3 Disentangling Privacy in Smart Homes

What is “privacy” in context of technology and socio-cultural aspects of cohabitation in the home? Our approach to privacy research in smart homes considers context, temporal changes, individual as well as group privacy, and will report on actual behaviour rather than just preferences. In order to meet these requirements, we propose an in-situ, longitudinal study with multiple households monitoring device usage, privacy salience, and privacy behaviour.

In aiming for a broader applicability of the findings, we need to consider a small number of different households and regard ethnography as infeasible. Instead we use a combination of action research, diaries, and interviews. Our longitudinal study will be split into three phases during which an increasing set of variables will be monitored. The first phase establishes a baseline of device usage in the home, considering routines and purposes. The second phase introduces new technology to the household. At the beginning of the last phase, the researcher

emphasises the ramifications of technology usage on privacy and highlights potential consequences. The diary study continues to monitor usage and privacy behaviour. Interviews with households mark the beginning and end of each phase. These interviews serve as checkpoints for researcher and participants.

This approach (“multi cohort prospective panel design” [44]) allows for suspicious interpretation of results [49], enabling the researchers to apply theories to guide actions and decisions as they see fit. The researchers can use this to verify theory that was developed previously (i.e. our findings from 5.2) joined by existing literature. We again see a good fit for a pragmatist approach as the researcher monitors changes while actively engaging with participants to transfer knowledge. This fits well with the pragmatist understanding of an intersubjective world and testing of warranted assertions. The observed variables and extracted warranted assertions can inform a set of variables that can be used for theory building or enhancement, i.e. we are considering the theory of contextual integrity [1].

#### 5.4 Implications for Policy and Product Development

In a first step, we plan to engage with product development. Our goal is to devise privacy design guidelines for smart home devices and to provide comments on existing software development frameworks, i.e. Privacy-By-Design, to make them fit for purpose.

We set up a series of focus groups with software designers from industry and academic researchers to discuss our findings. Using thematic analysis, we will provide suggestions for further research and to improve the existing framework and guidelines.

In further dissemination of our findings, we might liaise with policy makers, hoping to bridge some of the gap between policy and product development.

## 6 Future Work

In this paper, we reviewed literature on privacy, privacy and human behaviour, and smart homes. We then linked the identified research gaps with suitable methodological approaches. In addressing these gaps, research can provide a more rigorous understanding of the smart home context, and privacy within that context. Collaborating with policy makers and product designers, research can further facilitate improvements for people living in smart homes.

The proposed roadmap outlines five areas for future research in privacy, and we discuss our own research interests and intentions in addressing these. Moving forward we plan to deliver on the research agenda which is outlined in this paper.

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