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ORIGINAL ARTICLE

Embodied competencies and smart home technology in energy use: three ways users integrate smart heating systems in everyday practices

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Abstract Smart heating systems are increasingly entering the domestic sphere. Such smart home technology (SHT) intends to provide comfort, control, and convenience in the home as well as energy efficiency and energy flexibility. However, the success of these promises depends on users' ability to implement the SHT in everyday practices. In previous research, the importance of embodied competences acquired through previous experiences has gotten little attention. In this paper, we argue that broad scale implementation of SHT requires more knowledge on the interaction between previous experience in the formation of new competences and domestic heating practices.

In this paper, we explore how users integrate new smart technologies into their everyday heating practices in different ways by focusing on embodied competences. Based on 24 qualitative household interviews with SHT users, conducted through two Danish case studies, we identified three ways of approaching and integrating SHT in heating practices. First, the reluctant appears hesitant when adopting SHT and loses interest quickly. Second, the compliant follows orders and does what is expected by the new setup. Third, the committed encompasses a playful approach and shows strong interest in SHT design.

From this background, we find that embodied competences and previous experience are essential for how users adopt and integrate SHT in everyday life. For example, some users' previous experience, here younger and technically interested individuals, may match well with the logics of SHT, and for some users, here older and less tech-interested individuals, previous experience may not match well with SHT.

Keywords Smart home technology · smart heating · residential heating · households · practice theory · competences · everyday life

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Introduction

Digitalisation is seen as an increasingly important tool for modulating residential energy demand in climate change mitigation policy. Coupling of energy transition and digitalisation efforts is reflected in national policy, such as the publication Smart Grid in Denmark 2.0 by the Danish Energy Association (Energinet.dk & Danish Energy Association, 2016), as well as EU policy, e.g. the smart readiness indicator (Janhunen et al., 2019). As more renewable energy resources are used in energy production, energy systems need to change, expanding the boundaries to include residential buildings as active components in producing, storing, and modulating energy (Lund et al., 2017, 2018). To this end, smart home technologies (SHTs) are envisioned as the means to secure an efficient and flexible use of energy as well as promises of providing similar or better services of comfort, control, and convenience (Darby, 2018; Strengers, 2013; Strengers & Nicholls, 2017). Finally, especially for the older groups of society, the potential health and wellbeing benefits of SHTs are promoted, although adoption among these groups appears slow with specific barriers (Arthanat et al., 2019, 2020; Pal et al., 2018).

Research shows that smart home technology (SHT) has a great impact on everyday practices when integrated into households, for example in the form of changing routines, control, and comfort in homely environments (Darby, 2020; Furszyfer Del Rio, 2022; Hansen & Hauge, 2017; Hargreaves et al., 2018; Hargreaves & Wilson, 2017; Mennicken & Huang, 2012; Smale et al., 2017; Strengers, 2013). These studies also argue that bringing in new technology is not a straightforward process of adoption into established heating practices (or other energy-related practices), rather studies have shown that there are for example social barriers for SHT to be integrated into households' everyday life (Balta-Ozkan et al., 2013; Hargreaves et al., 2017). When smart home technologies enter the everyday life of householders, they risk disrupting practices performed in the home, and different strategies to comply with the new technologies take form (Hargreaves et al., 2017; Strengers, 2013). These studies find that SHT does not live up to expectations in real life settings, and an explanation on the partial and dispersed success might be that the competences needed to engage with SHT vary across householders (Larsen & Gram-Hanssen, 2020). Hansen and Hauge (2017) also studied user competences in relation to smart grid technologies, using practice theory to understand how know-how is embedded in changing practices and embodied in a "competent practitioner". For example, it took specific technical competences to integrate a new heat pump technology into a household's heating practice using the micro-generation system of the home so that the heat pump could run when the household's own green electricity was produced and not disrupt the desired heating. Hansen and Hauge write that by investigating competences, it is possible to describe how users become competent practitioners (Hansen & Hauge, 2017), for example when embodied experiences form into new energy practices. However, the importance of embodiment of practices and competences, i.e., how users act according to habits and previous experience, is largely missing, for example it is not addressed in recent reviews on SHT adoption (Marikyan et al., 2019; Sovacool & Furszyfer Del Rio, 2020). We find that the role of embodied competences is important to understand aspects of adoption and diffusion of SHT. Users (or practitioners) "carry" embodied energy practices with them, which influence their future practices, and existing values and experiences are found to form uncertainties and complexity of SHT use (Hubert et al., 2018; Marikyan et al., 2021).

In this paper, we explore the importance of users' embodied competences in implementing SHT in heating practices connected to the home. Heat consumption (space and water) constitutes around 80% of Danish households' energy use (Danish Energy Agency, 2021) and therefore holds great potential in reducing energy consumption levels. In this context, buildings as heat storage also shows potential as a way of transforming heat use in a more flexible direction (Le Dréau & Heiselberg, 2016). This is connected to the smart grid as a system for two-way connection and communication of energy (Hansen & Hauge, 2017). Thus, SHT for heat management, also referred to as home energy management systems (HEMS) (Sanguinetti et al., 2018), will be crucial in households' future energy consumption, and it is necessary to understand more about how such technologies can be integrated into households on a broad scale. Our guiding research question is therefore the following: How do embodied competences interact with SHT for heat management, and how does SHT reconfigure what constitutes a competent practitioner, or user, in heating homes?

This focus on the embodiment of competences and practices is guided by research based on a practice theoretical approach, which shows how users' embodied experience from previously performed energy practices form later practices (Hansen, 2018; Jacobsen & Hansen, 2021; Maller & Strengers, 2013; Strengers & Maller, 2017), for example when new technologies are implemented in everyday energy practices. We use this as the entry point and guideline for identifying approaches to interacting with SHT and ways of learning to use SHT before discussing scenarios of ways of living with SHT in everyday practices. From this, we describe three typical ways of adopting SHT and discuss how these strategies relate to changes in status as a competent practitioner in heating homes. We need to understand this variety of strategies to better identify barriers and potentials for future successful implementation of SHT, where the technologies will help all types of users in managing their energy consumption in a more sustainable way.

The paper starts with outlining literature on the visions and intentions embedded in the design of SHT for energy management. Then, we present the theoretical background, followed by methods and data. We present the analysis in two parts, followed by an outline of three typical ways of integrating SHT and a discussion of everyday life scenarios with SHT. Finally, we discuss findings and research implications.

Visions of "smart" energy use

In this paper, we will focus on one type of smart home technology (SHT), namely smart heating systems, which allow management of heating through for example apps, digital thermostats and IHD screens. For this purpose, we follow Furszyfer Del Rio (2022), who writes that smart home technologies (SHTs) refer to "[…] appliances that need to be digitally connected, provide some degree of automation and deliver enhanced services to occupants". SHTs are subject to many visions about their potential users and the impacts they will provide (Skjølsvold et al., 2015). These visions include increasing levels of comfort and convenience for users as well as energy efficiency and flexible demand. Strengers and Nicholls (2017) scrutinised the smart home visions of the industry that are pervaded by ideas of convenience and 'pleasance' adding to comfortable living in the home. Energy savings are most often of secondary importance in such visions, or the technologies are presented as a convenient and effortless way of saving energy, without giving thought to it or spending time on for example turning off lights around the home. Convenience is understood here as a process that simplifies and streamlines everyday practices by way of controlling smart technology and 'one-button' solutions that automate different activities in the home (Strengers & Nicholls, 2017). In a qualitative study, Aagaard (2021) explored convenience as a concept in smart home visions of industry actors. Here, convenience was understood as a sociotechnical imaginary that forms and adds meaning to smart home technology's role in everyday practices. For example, technologies should work easily and seamlessly, without much user involvement, and underpin or take over some of the practical tasks in the home. The user was not imagined to possess specific competences in these imaginaries, as the user was granted a passive role and the technology was supposed to work almost by itself, while barriers between human and technology was to be avoided (Aagaard, 2021). The design process of smart home technology (SHT) has also been criticised by Skjølsvold and Lindkvist (2015), who found that users are rarely included in the design process itself, which instead is driven by 'ideal-type personas'. According to Strengers (2013), the role of the user is to delegate control to technology, and the ideal user is envisioned as someone willing and able to pre-programme and automate everyday practices. Strengers wrote about the envisioned users as cast in a male-dominated industry and envisioned to be rational, technologically able and oriented towards efficiency and economy, e.g., of a home (Strengers, 2013). More recently, such gendered visions and use of SHT have been scrutinised further. For example, Furszyfer del Rio et al. (2021) write that in developing countries, there is a lower uptake of female users of digital and connected technologies compared to male users due to gendered patterns in education and skill building but also due to the fact that digital content, functionality and services of the technologies are not aimed towards female users. The gender imbalance in use of digital technologies, such as SHT, is also seen in the Global North, as Furszyfer del Rio et al. see a higher share of male adoption and use of SHT compared to female users in their UK study. Also, in Denmark, users of smart home technology were divided between 28% male users and 17% female users in 2019 (Statistics Denmark, 2020). Such unequal dynamics in households' use of SHT risk to support gendered asymmetry in household dynamics such as the distribution of household labour and conflicting issues of control (Aagaard, 2022; Furszyfer Del Rio et al., 2021).

Visions of potential SHT users are also reflected in policy, such as the European directive on energy efficiency (Directive (EU), 2018/844, 2018), stating that occupant preferences (on comfort) should not be compromised when delegating control to technology. Blue et al. (2020) criticise current representations of energy demand flexibility and the technical solutions to counter this, that is SHT, for being too simplistic in their understanding of everyday life and how energy demand develops. According to Blue et al. (2020), the narrow focus on meeting occupants' preferences overlooks the dynamics of these and how they change (often within a few years). The risks, according to Blue and colleagues, of the sole focus on technology is that energy demanding practices become less flexible, as the technologies embed expectations based on current levels of demand.

Strengers and Nicholls (2017) also see a negative potential for smart home technologies (SHTs) to increase both household labour, in the pursuit of making it more convenient, and energy demand. On the same note, Darby (2018) scrutinised the ideas and potentials of smart home technology and writes that the idea of home automation technologies as instruments for demand management and reduction came after technologies were developed to cater for luxurious and convenient living in the home. These studies indicate that large end-use efficiency gains are quite unlikely from SHTs in themselves, and that these technologies can instead contribute to increased levels of consumption (Darby, 2018; Hargreaves et al., 2017; Peffer et al., 2011; Strengers & Nicholls, 2017). In addition, complex set-ups of technologies in the smart home increase the level of devices that use (standby) energy and might hide the points of consumption that are found in everyday activities, as well as the knowledge and interest in reducing consumption in more intentional ways. Further, the control and customisation of SHTs require new technological competences in everyday practices such as heating, vacuuming, and turning lights on and off. In their study of households' use of SHTs, Hargreaves et al. (2017) find that the technologies are both technically and socially disruptive and that they require adaptation and familiarisation from householders, which can be a demanding task that requires a change in competences and habits. Similarly, Larsen and Gram-Hanssen (2020) find that smart home technology (SHT) for heat management reconfigures heating practices in very different ways, depending on the competences that householders possess. While SHT for management of heating is perceived and performed in an easy way for some, others find the technology disruptive or create workarounds to adapt to the technology (Larsen & Gram-Hanssen, 2020).

Thus, we see that SHT, in line with other energy technologies, can reconfigure everyday practices, such as those related to heating, including the competences needed in those practices, and potentially mismatch both embodied competences and the meanings of the practice, for example in relation to comfort (Madsen, 2018).

Theoretical background

Exploring the role of embodied competences in implementation of smart home technology (SHT), the paper builds on practice theoretical approaches that emphasise the role of previous experiences in energy practices. In general, this means that new technologies require adaptation to and integration into already existing energy practices, and embodied competences of users, or practitioners, which are formed by past practice experience, need to be adapted to new practices (Lahire, 2011).

Theories of practice have to a large extent been used to understand households' energy behaviour and the everyday consumption of energy (Gram-Hanssen, 2013; Hansen & Hauge, 2017; Shove & Walker, 2014). In this paper, we focus in on the competences of users that are embodied through the repetitive performance of a practice or through carrying out a practice such as heating a home. In this way, individuals are often given the role of "carriers" of practices or 'carrying out' practices (Reckwitz, 2002b; Shove et al., 2012). This paper is not the right place for a comprehensive discussion of the differences between individual actors as 'carriers' of practices versus embodying dispositions of practices, but emphasising the 'embodied element' of practices can be advantageous in understanding change and reproduction of practices (see for example Hansen, 2018; Heidenstrøm & Hansen, 2020; Jacobsen & Hansen, 2019; Wallenborn & Wilhite, 2014).

Thus, we focus on the term embodied competences, which refer to understandings of how to perform practices competently that are acquired and internalised in bodies through previous practice experience. For the analysis presented in this paper, we would like to outline three important points relating to the theoretical background. First, we consider social practices as the locus of the social (Schatzki, 1996; Schatzki, 2010). This entails that everyday practices, in this case related to services of residential heating and hot water, constitute the centre of the analysis at the same time as there is "room" for individual variances in carrying and performing practices (as previous studies of heating practices have shown, e.g., Gram-Hanssen, 2011, 2021; Madsen, 2017, 2018; Madsen & Gram-Hanssen, 2017). Second, we consider the primary role of individuals (users or practitioners) as carriers who perform practices (Reckwitz, 2002b; Shove et al., 2012). However, we emphasise the role of embodied experience of these practitioners. This refers to competences as a form of embodied knowledge or understanding which practitioners have acquired in performing practices throughout their lives (Heidenstrøm & Hansen, 2020; Jacobsen & Hansen, 2019; Sahakian & Wilhite, 2014; Wallenborn & Wilhite, 2014) or through unconscious ways of internalising practices, such as processes of mirroring others (Hansen & Jacobsen, 2020; Lizardo, 2007) or biological processes (Maller, 2016, 2019). In similar practice theoretical accounts, these 'embodied elements' of practices have also been described as personal trajectories within practices (or practice careers) (Backhaus et al., 2015; Warde, 2005), practice memories (Maller & Strengers, 2013; Strengers & Maller, 2017) and as embodied practices (Hansen, 2018). In this paper, we do not distinguish between the (minor) differences between these accounts. Third, and finally, we consider the role of objects in practices, such as radiators, thermostats, and control devices, in terms of how they are used in practice, rather than being detached from their application (Reckwitz, 2002a).

To sum up, this study is based on accounts of theories of practice. This means that we perceive competences as embodied understandings of how to conduct (heating) practices, which are acquired through previous practice experience and reconfigured in the performance of practices. Therefore, a new heating system, such as one which uses smart heating technology, reconfigures heating practices as well as the competences in these practices. What previously was recognised as a competent practitioner (user) in heating practices might be turned upside down. This might collide or match with the previous experience of the user and change the way a user perceives and performs heating.

Methods and data

The paper aims to add to the understanding of users of smart home technology (SHT) through the example of smart heating systems. Therefore, qualitative interviews have been carried out with different types of occupants who have smart heating control installed in their homes. Qualitative interviews are valuable in understanding the nuances of the use of SHT, the users' everyday life that the technologies enter into and the embodied competences of users and how these matches with the new technology.

The data analysed in this paper comes from two different research projects that have looked at the use of smart home technology for heating control in households. A total of 24 qualitative household interviews have been conducted across different cases. Below is a short description of each of the projects and the interview cases.

The first dataset was collected from November 2018 to March 2019, where 16 households were recruited from the Greater Copenhagen area, Denmark. Most households (12) lived in a recently developed neighbourhood in Copenhagen, considered to be middle to upper class. The four remaining households lived in a social housing estate for students, located outside of urban Copenhagen. The participants were mainly recruited through the local housing associations and were offered a small gift[1] for participating. The data was part of a PhD study examining smart home technologies (SHTs) and the reconfiguration of heating practices in a district heating network (Larsen 2021). Participants varied in relation to age (early 20s to late 60s), gender (50/50 distribution) and

[1] Cinema tickets

household typology (apartments and terraced houses), but there was an overrepresentation of participants from the middle and upper classes. Participants were recruited through flyers and emails and with the help of 'gatekeepers' such as local board members or administrative personnel (Larsen 2021). Data was collected until saturation was reached, which was when the topics of interest were assessed to have been covered satisfactorily and new themes ceased to appear in the interviews. Thereby we reached paucity in new information, which indicated data saturation (Guest et al., 2020). The topics of interest were everyday life routines, how occupants used smart home technologies for heating control, and general technology experience. The second dataset was collected between December 2019 and February 2020 until this had to be suspended due to the Covid-19 lockdown in Denmark in March 2020. Data was collected in two geographically different areas of Denmark: a city neighbourhood in Copenhagen and on an island. The city participants were on a middle to high income and lived in new-built low-energy apartments in a quite expensive area like the cases in the above study. This was not the case for the island participants, who were on a middle income and lived in terraced and detached houses in smaller towns. In the households that consisted of more than one person, both adult partners participated in the interview. The households consisted of singles or different sex couples, and only one of the households had a child living at home (several had grown-up children). The age of the participants ranged from mid-40s to mid-70s. Participants from the city households were recruited through direct contact via phone calls[2], and participants from the island households were recruited with the help of the local utility company through the former participation in a smart energy demonstration project. The topics of interest for the interviews were everyday routines and activities, comfort, heating, and airing and how occupants used smart home technologies, mainly heat control systems.

All 24 household interviews were conducted as in-depth qualitative interviews lasting between 1 and 2 h, and the interviews were conducted in the participants' homes. As part of the interview, participants were asked to perform a home tour, detailing how they performed practices in the different rooms and how they used their (smart) heating technologies. The participants were asked about their everyday routinised activities (inside and outside of the home), their use of energy technologies, including SHTs, and notions of energy use, comfort and convenience. The two interview studies were both concerned with households' use of SHTs and their everyday practices with a specific focus on heating and comfort. The interview guides used were quite similar, although prepared for two different research studies, as the interview guide for the first study was used as inspiration in developing the interview guide for the second study. All the interviews were digitally recorded and transcribed afterwards. Most interviews were conducted in Danish, apart from one interview in study 1 with non-Danish-speaking participants, which were conducted in English. For this interview, the interview guide was translated to English by the third author[3] (see interview guide in appendix). Most interview quotes have been translated from Danish to English by the authors for use in this paper, as the coding of the interviews were done in the original Danish (or in one case English) transcripts.

While combining two sets of qualitative data offers some limitation in terms of the validity of the results, we argue that due to the interlinkages between the scope of the two studies, both focusing on smart home technology (SHT) and heating practices, the benefits of combining the two datasets outweigh the drawbacks. Even though the datasets were gathered with two different, but related, research aims, a large part of the data centred on practices that involved managing smart heating systems and notions of comfort and control in relation to this. Thus, we found there was a potential for the two datasets to both strengthen and nuance each other in relation to the questions that we ask in this paper. Further, the aim in this analysis is not to validate interview quotes against each other, but to draw out different perspectives and experiences of adopting and living with SHT.

2 Contact information for these households was publicly available

3 The translation process was supported by Google Translate.

Coding strategy

For the analysis in this paper, the first and second author conducted an iterative coding of the interviews that focused on the householders' use and control of smart heating technologies and practices related to heating and comfort. The approach has been abductive, as our knowledge of the data indicated an interest in the strategies that households undertake in adoption of new smart home technologies. Following the initial coding of each of the data set, we did a first round of coding focusing broadly on themes of comfort, control and competences across the two data sets for the research interests of this paper. As this revealed new themes and nuances in the data, and between the authors, we consulted our theoretical framework and did a second round of coding on specific strategies related to the integration of SHT in heating practices that we identified during the first round of coding. This was to ensure consistency in coding across the two datasets. The identified strategies were further divided into the stages of approaching, learning and living with SHT. Finally, we combined the coding of the interviews to describe these different approaches (the "Approaching and integrating smart home technology in everyday energy practices" section) and derived the three scenarios (the "Discussion: everyday life with smart heating" section) using the same codes.

Approaching and integrating smart home technology in everyday energy practices

This analysis addresses different aspects, or stages, in the adoption of smart home technology (SHT) in daily energy practices related to domestic heating management. These include early stages of approaching SHT and later stages of integrating SHT in everyday practices. The analysis focuses on how embodied competences of users interact with SHT in heating practices and how SHT reconfigures what constitutes a competent practitioner (or user) in heating a home. Most often new skills are necessary to successfully learn how to apply SHT in practices or adjust practices to the technology. Based on the interviews, we identified three predominant approaches to the use of SHT: the reluctant, the compliant, and the committed. We see these approaches as typical ways that practices are changed when occupants learn to live with SHT: that is the practice configurations that come about in households.

The reluctant approach

The reluctant approach was apparent in a smaller number of interviews. However, this approach is important for understanding the full spectrum of approaches to SHT because it involved frustration, confusion, and a reluctance to engage with SHT, which was often connected to initial difficulty with managing the system. The reluctant approach was also sometimes critical and related to complaints and critique towards the technology, for example by referring to how the introduction of the technology was not good enough, how the manual did not contain sufficient information or how the technology was poorly designed.

A woman in her 60s explained the 'meeting' with the new technology as she and her husband moved into their new-built apartment as very confusing. This was partly because of problems with the installation of the technology, where some of the digital components had been mixed up and placed in the wrong rooms, which resulted in too much heating in some rooms: "It made the confusion total, and then they came at one point and checked it all… and put the right units in the right rooms (…) it made us totally confused, so we've had much confusion with that heating system (…) which is both about the [demonstration] project, but also about… the system itself and the installation of it" (Karen, 62). This older couple had spent much time and energy on figuring out how the system worked, and they still had some difficulties in making it work according to their preferences of temperature, specifically in the bedroom, which they wanted to be cooler than the other rooms.

This approach is not necessarily about the users' attitude towards technology in general. Rather than technical competences, the reluctant position seems to be about a mismatch between the embedded logics of the new systems on the one side and previously acquired competences and habits regarding heating on the other. The acquired competences can be related to other types of (older) technologies which the householder manages well. In other words, the new system does not deliver the expected service, and the occupant feels that it was much easier managing the old technologies. As Karen also said: “And learning to use this, right (…) it’s a completely different… well, we’re used to such heating apparatus where you turn it up and down” (Karen, 62). This mismatch between the user and the smart technology can also relate to different sets of meanings ascribed to heating. For example, the common combination of floor heating and smart heating systems results in a heating system that is not quite as flexible as the old systems with radiators, where you can easily turn the heating up and down and feel the change in temperature right away.

With this approach, the (new) technology is not found meaningful or useful in everyday practices. The smart technology is seen as complicated or illogical, and the use of it lacks meaning because it complicates a routinised heating practice unnecessarily. We found that the reluctant approach was primarily expressed by middle-aged to older users, or to put it another way, by those with embodied routines and competences for using traditional heating systems.

When needing help to manage SHT, the reluctant user reaches out to others. There are different options for this, which could include both professionals and peers. For some of the participants, their initial ‘meeting’ with the new technology started with an introduction by a technician, installer or the local caretaker of the housing organisation or owners’ association. Also, in many cases, the participants had received an introduction or manual from the responsible groups, such as developers or housing organisations, in connection with moving into a new apartment or having the smart system installed.

Support through social relations

A male participant living in a terraced house on an island explained the process when a smart heating system was installed as part of a demonstration project run by the local utility company:

“(…) when the system was put in, there was a technician visiting, and he showed me, like (…) we established the basic settings in the system together (…) then I just felt my way a little (…) and if then, I couldn’t exactly make it work… then I contacted the technicians to hear ‘then you should just do this and this’ and then it was just going on” (Thomas, 49).

This participant, who was very technologically interested and competent, felt that it was quite easy to continue to learn how to use the system after the introduction and with the ongoing support when he encountered problems with the settings. The introduction also included a discussion of temperature settings and how a heating schedule could fit with the participant’s everyday programme.

In this example, the installer or technician plays an important role in introducing the use of the system to the householders to promote successful implementation. It is important to mention that this participant was both technologically able and interested. He also liked to play around with the technology and try it out after the initial introduction. In another example from the same demonstration project, the technician (employed by the local utility company) played an even more important role, as an older female participant explained that whenever she felt there were problems with the heating system, she would call them for help*:* “(…) well, if I had problems, then I called them, and then a serviceman came and fixed it, right, so (…) it just worked” (Marianne, 75). This participant did not try herself to interact with the smart heating system, as she did not feel she had the competences, so she was very reliant on the technicians from the utility company.

Another strategy concerns how social and family relations can be handy for learning how to use new systems and technologies. For example, a young female participant explained that she had not contacted the technology support connected to the system: instead, she preferred to try to fix any problems herself and call her father for advice. When she had a problem with the connection, she unplugged the heating system: “(…) I pulled out the plug and put it back in, and then it all ran again. I think I am such a do-it-yourself type, who would rather try myself to solve it first. The first thing I did was call my father (…)” (Kirsten, 23). In this case the participant called her father, and he guided her on how to detect what the problem was, instructing her to look in the cabinet containing the heating instalment and touch the pipes to detect if there was a problem with the heating.

Several participants also mentioned internal Facebook groups connected to their housing as forums to discuss problems with the heating and technology, to see that others met the same problems or to learn from their neighbours (e.g., William/Emma, Charlotte/

Mia). Another example was an engineer, who himself had a more playful approach to the technology and became the go-to guy for the other neighbours, as his partner explained: "(…) he figures things out. He's the go-to guy for all the houses we have here. That filter, go and ask him, he knows (…) that's also why I don't know anything about it" (Sophia, 36). Such examples illustrate how talking to others or helping each other out in the neighbour community can be beneficial, especially for those who are part of demonstration projects or new-built housing units. Thus, this way of benefitting from social connection to others in a similar situation or with stronger technical competence seems very important for learning to handle new technology in the reluctant approach.

The compliant approach

The second approach that we identified was concerned with getting the technology to work in the best way using previous competences or acquiring new ones. We named this the compliant approach, as it entailed a lack of questioning the SHT. The approach is focused on making the technology work satisfyingly without spending too much time and mental energy. The participants that exemplify this approach did not find the use of the technology particularly difficult, but the use of it did not entirely match their competences and interests. A female participant explained her experience with the technology:

"I wouldn't say frustrating or difficult. I don't know if I would say easy either. I mean, I think it also depends on how much you use it (…) I think we've been a little bit laissez-faire about it maybe, I mean not really bothered by it too much. We could probably do a lot more, complain a lot more about the faults that maybe there are, but we haven't. I guess it's because we don't freeze, and we're… I mean relatively speaking we're comfortable, that's kind of okay" (Elizabeth, 38).

With this approach, the participants tend to accept the new technological system as providing the service needed without too much engagement or effort. The occupants use the technology in a simple way that suits their daily needs, as they do not prioritise engaging more deeply with the technology or lack the competences to do so. This is also explained by an older male participant, who does not use the IHD screen to regulate the heating, but instead uses the digital thermostats in each room: "I'll say that it's something like (…) it's so close to being as good as I wish for. And then you don't search for more advanced solutions when things work" (Kristian, 70). He explained that he finds the system quite simple to use because he uses it in a 'primitive' manner, where he adjusts the temperature on the thermostats up and down according to his bodily sense of warmth or coolness instead of programming the temperature settings in the system.

Thus, the compliant approach seems to primarily draw on previous acquired competences, and if these are not sufficient, time and effort need to be invested in acquiring new (technical) competences, which to the participants seem like a routine obligation rather than a hobby (as in the committed approach) or a burden (as in the reluctant approach). Therefore, the compliant participants do not engage more strongly with the technology.

Try it out

The compliant tended to start by themselves and try to figure out the technology, for example by using default options, reading manuals, pushing buttons, and in general trying things out. This strategy requires competences to read and understand manuals as well as a good portion of patience and effort. Relying on what could be referred to as 'embedded understandings', for example default options, is important. For example, a younger female participant explained how she settled on the temperature for when she's out: "I actually, most often I think it is because that was what it [the SHT] suggested. Then, it settles to 12 [degrees], so it is not completely turned off, but it still runs without much heating. And I really like to use it when I need to be away from home" (Anne, 25). This illustrates how default settings can quietly be integrated into routines. Standard and default options can play an important role without much reflection from the user. In the way that this participant described, it almost seems like the system itself chose the temperature for her, but most often such reflections might not be articulated.

The committed approach

The third approach refers to situations where new SHT was experienced as fun and interesting, where the technology is experienced as a toy as much as a practical tool to service everyday practices. We termed this approach committed because it reflects eagerness, enthusiasm, and interest in finding ways to use the technology. Most of the participants that exemplified this approach were engaged in this manner only for shorter periods, for example in the beginning of having the technology in the household.

One younger participant described how she and her partner approached the new smart heating system:

"(…) to begin with, we played with it like crazy because it was a fun new technology, then we regulated it to what we liked, and then at one point when we're going on holiday, then I think we'll play with it a bit again, because then we're regulating our holiday mode, right (…) otherwise it will just be allowed to run" (Carina, 25).

This couple liked to try out the technology and play with the settings; however, once they had regulated it to satisfy their preferences, it was allowed to merely act in the background as a system serving their heating practice. The committed participants often used the potential of the technology to program a schedule for their heating routine so that it would follow their daily routine of being at home or out for work or school. As Carina further explained, she and her partner rarely regulated the heating at home because it was scheduled according to their routine: "(…) now I don't do it so often because now you can set it after when you, approximately, go to bed and then you can set the temperature to fall a bit. And I'm a big fan of that" (Carina, 25). The positive approach in this position was also shown through appreciation of some benefits of SHT. For example, a male participant highlighted the ability of the technology to save both time and money: "(…) I can control that it should turn down, and it should turn up, and I can install it all… and then it can take care of itself (…) therefore, it saves me time (…) and it also saves money" (Allan, 40s).

This approach refers to participants that are often very technologically competent and interested, specifically regarding connected technologies such as smart phones and iPads. For example, a young female participant explained that she never uses the thermostats to regulate the heating, but always uses the app connected to the system because "(...) it gives a much better overview" (Kirsten, 23). She further explained that when the smart heating system was installed, she connected it to the internet herself because she was tired of waiting for the installer to do it for her: "(…) and they didn't connect it to the internet (…) so then I went myself and connected it to the internet, and when I did that, I connected it to the app at the same time (…)" (Kirsten, 23). The committed approach relates to previous technical experience and competence, as there seems to be a good match between the interest, engagement, and competence from previous practices interacting with technologies into the practices based on SHT.

Playing around

The committed tended to have a playful learning approach to SHT. The participants in this approach find it fun and interesting to get to know the technology by trying different options. This approach is exemplified by households that, at least in the beginning, were experimenting with the opportunities presented by the new equipment.

A young female participant explained how she and her partner pushed the buttons on the technology:

"Yes well, I just went and pushed a lot of buttons (…) and then [partner] went and downloaded the app right away and played with it there. And then you could say we could 'counter interact' with each other, so if I pushed it to be 22 degrees and he then writes something else on his smartphone, then I don't know which one (…) but we kind of agreed on (…) then we talk about how high, how much warmth we'd like" (Carina, 25).

Several of the participants in these examples had technical backgrounds, such as educated engineers, or were highly interested in technology and possessed the technical competences to work with technology. A male participant explained that he rarely used manuals:

"I just sit down, then I take the gizmos out, and then I just sit testing them and figuring them out. Then I google a bit. [partner: 'He's also an engineer'] Yes. I think it's funny. I never read a manual. But (…) I also try to find out, what it is (…) It shouldn't break, right. But I think I was the only one who had figured that I should change the filters. Then there were all the neighbours, they had never done it" (Ethan, 41).

Another male participant showed how he used the smart system: "Now I just try to set it to 22.5 [degrees]. Then it should send it up to this one up here [IHD] and tell that it is 22.5, and it changes to 22.5, so that's fine" (Noah, 35). He explained that he read some of the manual that was provided, but then he just started pushing buttons: "(…) I read these 10 pages from [technology company]. But I think my approach has been like my approach is to all other manuals. You read it fairly quickly and then you also just start trying" (Male, 35). This also points at how such an approach may require strong technical competence and curiosity in technical systems. In this way, the new technology becomes a way to build on already acquired competence by testing and experimenting. Compared to the 'try it out' strategy, the competence is not just a means of learning to use the specific technology and get everyday life to function, but instead learning new things becomes a goal.

Discussion: everyday life with smart heating

How users approach and learn about smart home technology (SHT) in everyday life has consequences for how they end up living with the technologies. In this section, we discuss the analysis through three possible scenarios that emerge based on the analysis, identifying possible consequences of how SHT enters the households. The scenarios exemplify different ways of living with SHT and are constructed based on the empirical material as a whole and the analysis of the three different approaches above. This extends the understanding of how differences in embodied competence might contribute to different scenarios of SHT implementation and acceptance.

Figure 1 summarises the analysis by illustrating the links between the analysis and the three scenarios. It is important that these are perceived as ideal typical positions. This means that the households from the study cannot be put into exact boxes, but instead represent various approaches (at different stages) and various learning strategies (at different times). In this way, the reluctant approach (A) is described as passive and links to a strategy of reaching out and scenario 1, where the occupant tends to stop interacting with the technology. The compliant approach (B) is described as loyal and links to a strategy of learning-by-doing and scenario 2, in which the occupant finds ways to adjust to everyday life with SHT. The committed approach (C) is described as active and links to a strategy of playing with the technology and scenario 3, in which the occupant finds that SHT offers positive new options in heating the home Table 1.

Scenario 1: "We just don't use it anymore"

Some of the participants in the two case studies expressed frustration with the SHT, distrust in the system and a lack of engagement with using the technology. This relates to a lack of control and competences needed in providing home heating with the technology, and thereby a loss of status as a competent practitioner. However, it is also expressed as a lack of meaning; for example, participants did not see how the technology improved their heating practice, did not feel a need to automatise and schedule their heating, or participants felt that the technology changed their meaning of heating and comfort. This could for example be because the occupant's experience of the heating system was digital instead of manual and bodily, as with radiators. This change has also been seen with other types of heating technologies (Madsen, 2018). Also, for some, it did not make sense to schedule their heating because they were home much of the day or were not away from home during the exact same timeframe each day. This was related to their everyday schedule and the way they performed other everyday practices. In this scenario, if there is an initial open-mindedness and engagement with the technology, it quickly disappears. This might cause the occupants to abandon the smart system, and where this is not possible, it might lead to frustration over the lack of control of the heating system and loss of status as a competent practitioner in providing the desired comfort in the household. Some of these participants started out with an engaged interaction with the new technology, trying to learn how to use the different options. But this engagement disappeared when the technology did not figure as meaningful in heating the home, as 'old' ways of doing this seemed more appropriate. This could for example be regarding scheduling heating or using holiday mode. One participant [Kristian, 70] explained that he did not actually use the smart heating system in the form

Table 1 presents all the interview participants. All participants have been anonymised

Pseudonym(s) and age	Household size	Residential type	SHT features	Heating installations**	Settlement
Peter (21)	1 household member	Apartment	Remote control (App, IHD), smart thermostats	Underfloor heating in bathroom, radiator in other rooms	Outskirts of city
Anne (25)	1 household member	Apartment	Remote control (App, IHD), smart thermostats	Underfloor heating in bathroom, radiator in other rooms	Outskirts of city
Carina (25)*	2 household members	Apartment	Remote control (App, IHD), smart thermostats	Underfloor heating in bathroom, radiator in other rooms	Outskirts of city
Kirsten (23)	1 household member	Apartment	Remote control (App, IHD), smart thermostats	Underfloor heating in bathroom, radiator in other rooms	Outskirts of city
Simon (51)*	2 household members	Terraced house	Smart thermostats, energy feedback	Underfloor heating in all rooms	City
Jan (45) and Carla (43)*	3 household members	Apartment	Remote control (App, IHD), smart thermostats	Underfloor heating in all rooms	City
Noah (35)*	3 household members	Apartment	Remote control (App, IHD), smart thermostats	Underfloor heating in all rooms	City
Alexander (58)*	5 household members	Detached house	Remote control (App, IHD), smart thermostats	Underfloor heating in all rooms	Suburb
William (23) and Emma (21)	2 household members	Apartment	Remote control (App, IHD), smart thermostats, energy feedback	Underfloor heating in all rooms	City
Jacob (37)*	4 household members	Apartment	Remote control (App, IHD), smart thermostats, energy feedback	Underfloor heating in all rooms	City
Charlotte (52) and Mia (45)*	3 household members	Apartment	Remote control (App, IHD), smart thermostats, energy feedback	Underfloor heating in all rooms	City
Benjamin (45)*	5 household members	Terraced house	Smart thermostats, energy feedback.	Underfloor heating in all rooms	City
Liam (58) and Olivia (55)*	3 household members	Terraced house	Smart thermostats, energy feedback.	Underfloor heating in all rooms	City
Sophia (36) and Ethan (41)*	4 household members	Terraced house	Smart thermostats, energy feedback.	Underfloor heating in all rooms	City
Andrew (56)	1 household member	Apartment	Remote control (App, IHD), smart thermostats	Underfloor heating in all rooms	City
Elizabeth (38)*	4 household members	Apartment	Remote control (App, IHD), smart thermostats	Underfloor heating in all rooms	City
Poul (70), Karen (62)	2 household members	Apartment	Smart thermostats and IHD	Underfloor heating in all rooms	City
Kristian (70)	1 household member	Apartment	Smart thermostats and IHD	Underfloor heating in all rooms	City

Table 1 (continued)

Pseudonym(s) and age	Household size	Residential type	SHT features	Heating installations**	Settlement
Nanna (46), Allan (40s)*	3 household members (1 adolescent)	Apartment	Smart thermostats and IHD	Underfloor heating in all rooms	City
Thomas (49)	1 household member	Terraced house	Participated in project with smart heating technology	Electrical radiators and air-to-air heat pumps	Town, Island
Svend (70)	1 household member	Townhouse	Participated in project with smart heating technology	Electrical radiators, air-to-air heat pump and stoves	Town, Island
Niels (64), Susan (61)	2 household members	Detached house	Participated in project with smart heating technology	Electrical radiators, air-to-air heat pump, stove and underfloor heating (bathroom)	Town, Island
Marianne (75)	1 household member	Townhouse	Participated in project with smart heating technology	Electrical radiators and air-to-air heat pump	Town, Island
Johannes (70), Ruth (69)	2 household members	Detached house	Participated in project with smart heating technology	District heating (underfloor), electrical radiators and stove	Town, Island

*Only pseudonyms and age of those interviewed: not all household members were present at the interviews

**Most households were supplied by district heating, while some island households were supplied by electricity

of the IHD screen and schedules but primarily used the digital thermostats in each room to adjust the temperature because he felt this was easier. Some other participants replied that they had not tried to use the holiday settings, they did not see the potential of using holiday mode, or they forgot to turn the heating back on when returning from holiday. These participants did not feel that the holiday mode function in the technology added something positive to their heating management.

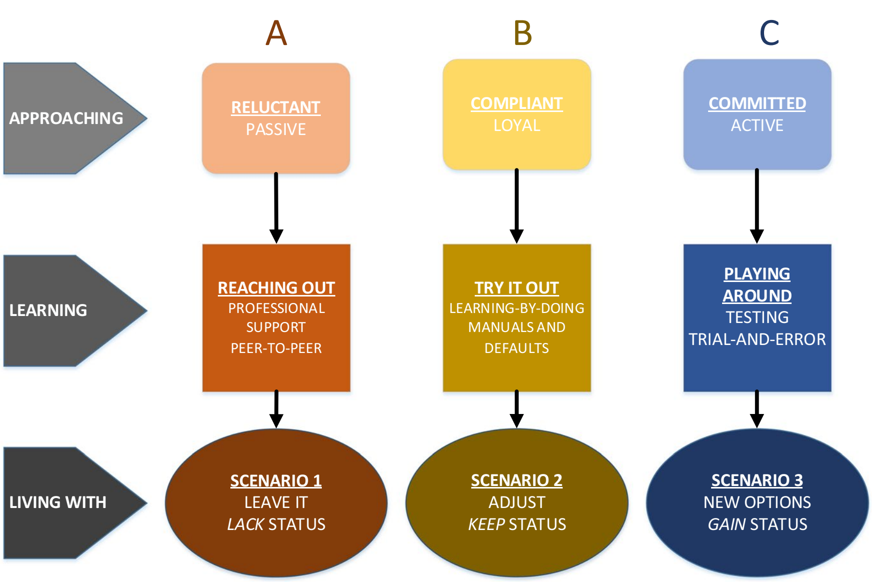

Fig. 1 Summary of analysis leading to three scenarios

Scenario 2: 'Then I just press "home"'

The smooth adaptation to an everyday life with SHT was also present in our study. This scenario represents a learning-by-doing approach to the technology, which includes adjustments in everyday practices and acquiring new competences, learning about the technology, and trying different options. Sometimes it required some (creative) adjustments or workarounds in the user's daily life, but this figured like many other smaller adjustments of everyday practices that did not seem too disruptive for the occupant. In this scenario, the SHT is quietly and conveniently integrated into the heating practices of the occupants that in this study entailed both younger and older participants. The integration is a task that needs to be done in the best way possible, often with a minimum of effort and interest and sometimes also without all the matching competences. This relies on trust in one's own abilities to make it work, without questioning the technology as such. For example, one participant (Carina, 25) explained that her heating practice now integrated the SHT scheduled heat and artefacts such as additional clothing or an electric blanket to warm her if she went to bed later than usual, had a longer morning at home or came back home earlier than anticipated. She would then overrule the system by pressing 'home' at the IHD screen to indicate that the system should start heating and then use the blanket until the room was sufficiently warm so that she felt comfortable sitting and working at home. Some of the participants who were compliant with the SHT system also experienced occasional overheating of their home, for example, if the sun was shining all day. This meant that they had to open doors or windows to cool the apartment, and they did not find it meaningful, in terms of their comfort, on these occasions to turn the heating down. The compliant approach is a strategy to make the technology useful within the competences and daily structures of the household so that the household is provided with heating service, although maybe not in the most optimal way according to the design of the SHT. In this way, the status as a competent practitioner, or user, who knows how to manage the heating system and provide satisfying comfort is sustained and not challenged too much by SHT, although this sometimes necessitates some adjustments or workarounds for the occupant. This scenario also fits with previous studies which have found that users who think SHT fits their daily tasks also tend to perceive the technology as useful and providing more satisfaction (Marikyan et al., 2021), and how high compatibility with existing values and experiences tends to make experienced changes following the new technology less strong with fewer uncertainties (Hubert et al., 2018).

Scenario 3: 'Just find a program that fits our needs'

This scenario describes the cases where the strong engagement and excitement outlive the initial phase. Learning about SHT is not just about providing comfort for the participants, but it is fun, challenging and exciting to 'play' with the new technical equipment. These users were often younger participants in the study or participants who held a strong interest and competence in relation to technology. They also had a great amount of trust in (new) technologies, control, and data storage, and they might gain a stronger status as competent in the heating practice following the adoption of SHT. The obvious positive experience with SHT is when providing satisfying heat and control for occupants, but for some of these users, SHT also brings new opportunities to control their heating. For example, some participants felt that it had become easier for them to manage the heating because the smart heating system made more sense to them in their heating management than older heating technologies such as radiators without indication of set temperatures. This is another way that the digital perception of heating influences users in their heating practices, as these participants find it more meaningful to assess their thermal comfort through the numbers on a screen instead of for example a radiator that is hot or cold. In this way, SHT means that they strengthen or obtain a status as a competent practitioner or user. Moreover, SHT can almost become a hobby project in the home, especially for those occupants that are very technologically competent and interested. This may fade when the technology is integrated if the participants feel that their heating runs smoothly, and they feel in control of it. However, for some participants the attraction of the technology is also that if they manage to programme it in a way that satisfies their needs, they feel the system takes care of itself and do not have to interact with it or adjust the settings as often as with older technologies. The committed users are the user group that fits most with the visions of SHT as shown by, e.g., Strengers (2013).

Embodied competences and implementation of smart home technology

Larsen and Gram-Hanssen (2020) already showed how SHT reconfigures practices of heating in different ways according to the embodied experiences and competences of the occupant, together with engagement towards the technology and existing norms (i.e., comfort) and material surroundings. The above scenarios show that for some occupants there is a mismatch between their acquired competences and the new technologies, and for others there is a better match between competences (e.g., from other practices, such as using smartphones and apps) and SHT, while they were maybe not as competent in using the services of old heating technologies. Thus, some of the users' competences match better with old heating technologies, and some match better with SHT. These three typical ways of adopting and living with SHT exemplify how the different strategies relate to changes in status as a competent practitioner or user. We need to understand this variety of strategies to better identify barriers and potentials for future successful implementation of SHT.

Users' lack of competence to use the technology could be seen as a barrier, but the analysis shows that 'lack of competence' can take various forms and relate to the meanings ascribed to, for example, heating practices. An understanding of how this varies with previous and embodied experiences can be useful for the implementation of SHT in different user groups. There are also potentials to be found in these different strategies. For example, embodied competences can vary with age and gender, and therefore, the introduction of SHT can potentially both challenge and reinforce household roles and relations between household members. In this study, it was primarily the younger and technologically competent users, across genders that were competent in the committed way at using SHT. More of the older participants were reluctant to or critical towards using the smart heating system. For some users, it will be an easy and positive change in heating practice, and for some, it will not. SHT reconfigures practices, and therefore, it is important to consider that occupants, or users, do not equally enter into new 'positions' or into new practices of heating and that the status as a competent practitioner might also be reconfigured. Such generational differences and potential reconfigurations of household roles may open up opportunities to better promote efficient energy use and stronger equity in everyday practices related to energy use. However, SHT can also reinforce age-related differences, as noted in this study, or reinforce gender roles in households, as seen in other studies (e.g., Aagaard & Madsen, 2022)

Conclusion and research implications

This paper set out to explore the role of users' embodied competences, acquired through previous experiences, when approaching and learning how to use smart home technology (SHT). The analysis points to three scenarios regarding how SHT is integrated into occupants' everyday life. The study has shown how smart heating systems do not just change heating practices, but also reconfigure what constitutes a competent practitioner, or user, in heating practices. SHT requires different competences than those of previous systems, which can conflict or match with the embodied competences of the user. In other words, the 'rucksack' of previous experience and embodied competence is important when approaching and learning to live with new (smart) heating systems, and this seems to have an impact on whether SHT is met in a reluctant, compliant, or committed way by users. In this paper, we investigated smart heating systems, but the importance of previous experience and embodied competence might also be relevant for other smart home technologies (SHTs).

SHTs most often embed or rely on relatively static assumptions of what constitutes competences in a practice, such as heating, as well as user competences in using the technology. However, what is a competent performance of heating practices, with new or old technologies, and thereby what is perceived as a competent practitioner, is constantly changing according to reconfigurations of the specific heating practice and changes with technologies. Therefore, when smart home technology (SHT) reconfigures practices, it is important to consider that occupants do not equally enter new 'positions' or into new practices and that the status as a competent practitioner might also be reconfigured. Thus, it is crucial to consider the ways SHT reconfigures practices, as this requires and creates new forms of competences.

The main message from this paper is that where lack of competence, technical skills or information could be identified as barriers in research and policy, the results in this study point at how variation in acquired competence relates to previous experience and suggest that variations in such experiences from previous heating practices are important in complex ways, which might not be captured well by smart readiness indicators or stated preferences. This means looking at the occupant as a practitioner in everyday life, who does not necessarily correspond with the conventional, rational user or the ways smart technology systems are automatised. However, requiring new competences from practitioners might also have consequences for social relations between household members that can change or reproduce existing roles and the related status within the household. This especially relates to the gendered household roles and intergenerational differences. Therefore, we suggest considering the relation between (1) required know-how for controlling SHT, in the form of embedded understanding in design and narratives, and (2) acquired and embodied competence of the practitioner, for example intergenerational differences and (3) household relations, for example gendered division of household tasks. Overseeing the reconfiguration of practices including competences, risks losing some groups of people in the introduction of SHT and the transition of energy systems and, furthermore, risks creating new inequities in households' everyday life as well as changing power relations within and between households.

Future research on SHT adoption and implementation could benefit from more attention to previous experiences and embodied competences. In terms of methodological design, following users or households over time from before installation of smart heating systems, during the initial stages of living with such new heating systems, to the later stages where the heating systems would have reconfigured existing heating practices, could add important knowledge on everyday life with SHT.

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Declarations

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