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WARMTH IS MORE THAN TEMPERATURE: SENSORY USER EXPERIENCE AND SMART HOME ENERGY TECHNOLOGIES

Research paper

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Abstract

Smart home energy management systems (SHEMS) enable households to play an active role in the ongoing energy transition. We conceptualize sensory user experience and analyze what sensory experience in relation to SHEMS consists of. Sensory user experience is critical in the design and adoption of ubiquitous home technologies. Yet, it has been poorly studied in Information Systems (IS) research. Sensory ethnographic approach was applied in the framework of value-sensitive design in the study of 21 families. The findings suggest sensory user experience intermingled with energy consumption in homes consists of intertwined sensory and affective factors Interviewees' quotations and mental maps show home is a social and sensory place and sensory user experience is a social, negotiated, shared experience. Different parts of home impose different requirements for sensory user experience, and sensations of warmth, view, scents, sounds and light are relevant in it. The comfort of the nucleus of home is not to be compromised, yet there are opportunities for energy management. When sensory experience in home is understood, SHEMS may be designed and used to improve sensory experience. The paper also contributes to the methodological discussion on sensory ethnography in value-sensitive design and energy technology research.

Keywords: Sustainable practices, Sensory user experience, Smart home energy management systems, home.

1 Introduction

The ongoing energy transition is changing the way energy is produced, managed and consumed. The change will touch all parts of society, homes included (Strengers, 2013; Lennon, et.al., 2019). The current roles of energy suppliers and consumers are mixing and merging as households will increasingly produce, sell and store energy. They may also shift or adjust the load on the electricity grid that can be used to foster the use of largely weather-depended and variable, renewable energy sources. People in the home may become 'co-managers' of supply of electricity and grid balance (Gellins, 1996; Smale, Spaargaren and Vliet, 2019; Vliet, Shove and Chappells, 2005). For achieving global ecologic sustainability goals, it is necessary to activate and support people in homes in energy management. New technologies, such as smart home energy management systems (SHEMS) help people to take more active role in the energy scene by enabling energy management benefiting both the homes and the society (Wilson, Hargreaves and Hauxwell-Baldwin, 2017; Katzeff & Wangel, 2015; Van Dam, 2013).

In order to support ecologically sustainable digital practices of homes and families, multiple dimensions of home (social, individual, emotional, material, technical, economic, time, place etc.) must be considered in technology design (Buswell, Webb and Mitchell, 2015; Labanca and Bertoldi, 2018; Wallenborg and Wilhite, 2014). Sensory, material and social reactions caused by the experience of a

place shape the way people feel in, act, and value that place (Sunderland et al. 2012). The ways energy use is managed in homes convey many sensory aspects, e.g. indoor temperatures, availability of warm water, lightning, and sounds and scents of cooking and washing. However, energy is invisible and the use of energy is abstract, while it can be made visible in research by observing and re-enacting the daily practices, into which energy use is intertwined (Coughlan et al., 2013; Leder Mackley and Pink, 2013; Maréchal and Holzemer, 2018; Mitchell et al., 2015; Pink, 2012; Pink and Leder Mackley, 2012). Important is to note that in home the user of home technologies might not be an individual, but a family (Tuomela, Iivari and Svento, 2019). All this indicates that various kinds of sensory, social and material dimensions of home influence the use of energy management and other ubiquitous home technologies. Yet, there is a lack of Information Systems (IS) studies addressing this complexity.

This study will introduce a sensory lens for IS research for exploring the complexities of home as the context of use and family as the user of SHEMS. In Human Computer Interaction (HCI) research, various approaches have already been proposed to study and design for sensory interaction (e.g. Hornecker and Buur, 2006; Kapoor and Picard, 2005; Slater, Usoh and Steed, 1995; Haque, 2004). Sensory research has already been applied in the context of sustainable HCI (e.g. De Giorgi, Lerma, Allione and Buiatti, 2011; Mo et al., 2009)) or more specifically in the context of energy use and related technologies (e.g. (Haines, Mitchell and Ross, 2015; Pink et al., 2013)). Inspired by this stream of research, this study will address the IS topic of how to introduce and examine ecologically sustainable digital practices within homes and families. We respond to calls to further understand the role that IS can play on sustainability (Elliot 2011; Watson et al. 2010). For IS research, home and families represent less studied contexts and user groups, studies on which nevertheless have been called for within experiential computing (Yoo 2010). Ecological sustainability in the context of home has been studied in a couple of IS studies (Corbett & El Idrissi 2017, Kroll et al. 2019, Lossin et al. 2016, Shevchuk et al. 2019), while these studies focus heavily on the individual and on factors shaping his/her decision-making process, neglecting the intricacies of the context of home and family as the user.

This research is a part of a value-sensitive (Friedman, 1999), experience-centred design process (Wright and McCarthy, 2010) for designing future SHEMS and other smart home technologies. Applying sensory lens (Pink et al., 2013), we conducted in fall 2018 semi-structured interviews and home tours focusing on sensory, material and social aspects of everyday energy-entailing routines and the meanings families create in their home. In this research, we conceptualize and empirically examine 'sensory user experience' of SHEMS. Previous work so far has failed to address the sensory user experience of SHEMS. Addressing it is a challenge as such systems, in line with the vision of Weiser (1991: 3) are "those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it". Sensory user experience of such a disappearing technology includes both interaction with the actual technology and with the environment where technology is placed. This research addresses the following research question: What does sensory user experience of SHEMS in homes consist of? The results of this study indicate interesting paths for future IS research on SHEMS and related ubiquitous technologies used in homes and by families as well as opportunities and preconditions for the design of SHEMS.

The paper is structured as follows: The next section gives an overview of the state of art in the sensory research and defines sensory user experience. Furthermore, we review the relevant research in home and smart home energy technologies. The third section presents the research design, and the fourth section the findings. The fifth section discusses the findings. Conclusions are drawn in the last section.

2 Sensory user experience and smart home technologies

2.1 Smart home energy management technology

SHEMS comprises sensors, interfaces, appliances and devices networked together to enable automation as well as localized and remote control of home energy use (Marikyan, Papagiannidis and Alamanos, 2019; Zhou et al., 2016). The key functions of SHEMS are to monitor, control, and optimize

the flow and use of energy in the home. SHEMS may be integrated into the smart grid and include microgeneration technologies such as solar panels, a storage for energy, and an electric vehicle as well as a growing number of home energy consuming devices (Lobaccaro, Carlucci and Löfström, 2016; Zhou et al., 2016). SHEMS communicates through cloud service, and besides the user's settings uses the weather forecast, information on electricity prices, outdoor and indoor temperatures and humidity to adjust the energy consumption. The load shift capacity may be used to increase demand flexibility. SHEMS can be called 'smart' as it learns and adapts to changing conditions, thus offering users beyond mere automation. The system behind the user interface (UI) is complex, and for the user there are several layers of interaction. Besides direct user control through a 'traditional' UI, householders' everyday practices and moving in the home may result in changes in SHEMS functioning, for example activating other heat sources (e.g. fire in the wood stove, cooking) and opening/closing doors or windows causing the movement of warm or cool air in the home.

The SHEMS used in our empirical study consisted of room-based heating and use water heating management, based on user settings, electricity prices, indoor (room) and outdoor temperatures and humidity, the weather forecast and learning algorithms.

2.2 Home as a space and as a place

Home as a research environment is growing in importance (Easthope, 2004), especially what comes to technology (Coughlan et al., 2013). Homes and families can foster ecological sustainability through smart home technologies; however, so far there is little IS research on the topic in domestic settings (Lossin et al. 2016). Home is a special place with private and intimate nature and with cultural patterns and norms (Harrison and Dourish, 1996), where people sense the feeling of belonging. Home is not only a built, physical building, but also an expression of the self (Cooper, 1974/2014), and a social construction (Easthope, 2004). Important meanings of home for its occupants are 'home as relationship with family and friends', and 'home as reflection of one's ideas and values' (Després, 1991). Home as a research environment poses particular features and challenges. For example, home is a private space, but the perspectives of privacy are dynamic and vary by person in the home (Coughlan et al., 2013). Different types of relationships form a significant part of the meaning of home, and the roles and activities played there (Coughlan et al., 2013). In the home, people attach great importance to sensations such as comfort and relaxation. Other people, memories and space are usually valued more than technologies or material objects, which serve rather saving time, creating the desired sensation, or for other goals, though sometimes they may invoke feelings of pride, appearance and prestige (Haines, Mitchell and Cooper, 2007). Home is actually a mix of sensory spaces: thermal space, acoustic space, olfactory space, and so on. Immediate sensory perceptions are interpreted through cultural norms, which influence how the home as a sensory place is experienced and modelled (Hall, 1966).

Smart homes adapt to users' behaviour and increasingly "our behaviour becomes simultaneously the behaviour of the building we occupy" (Jäger, Schnädelback and Hale, 2016). Homes with smart technologies may actively influence inhabitants' behaviour. Yet, there is little research on the role of space or place in interaction (Dalton, Schnädelbach, Wiberg and Varoudis, 2016). Human interaction with technologies should be studied in place, with a situated view (Madsen and Gram-Hanssen, 2017; Luck, 2016). Every home is different, and the constitution of families vary. Therefore, understanding the needs, values and meanings people relate to energy use in the home is of outmost importance in the design of home energy systems which influence the whole home and all its inhabitants.

2.3 Sensory, material and social in energy use

Energy use in homes has evolved from complexity to simplicity and is changing to complexity again (Lewis, 2011). The ongoing energy transition requires supporting technologies and services in homes, such as SHEMS. Energy use in the home is part of householders' everyday practices, and an outcome of manifold material, social, individual, technical and economic factors (Levold and Aune, 2003; Aune, 2007; Shove and Walker, 2014). The meanings of the use of energy and SHEMS is created of-

ten within social, everyday situations (Maréchal and Holzemer, 2018), and they emerge and are experienced in various ways (Gieseking et al., 2014). Therefore, energy use should be studied as part of a wider experiential environment and flows of practical activity (Leder Mackley et al. 2013; Kotsopoulos et. al., 2017).

Research on home energy use has been based on the assumption of rational individuals, and the social, material and perceptual aspects have been given little attention until recently (Wallenborn and Wilhite, 2014). Echoing the practice-turn in social sciences during the recent decades (Schatzki and Knorr-Cetina, 2001), practice-oriented technology research examines people and technologies in time and place, e.g. how the technology fits into our everyday practices (Kuutti and Bannon, 2014). Energy use particularly is hidden and intertwined in the everyday and digital practices and routines (Byrne and Bartiaux, 2017). Bodies, as spatiotemporal entities, engage in social life through practices (Wallenborg and Wilhite, 2014). Our bodies are present and involved in all practices we perform. Many bodily practices are repetitive, but they are also subject to readjustments and creative changes if the demands or conditions of a situation that requires (Thévenot, 2001). How we perceive and interpret the bodily and material sensations affects energy use. For example, the perception of comfort has changed as we have been able to heat homes and water without much effort. Householders prefer to live in more spacious homes, consequently consuming more energy for heating and maintenance of home (Ortiz, Kurvers, and Bluyssen, 2017). All in all, there is a growing interest in comfort and embodiment related to energy consumption, yet there has been little discussion on the overall sensory user experience and its implications on energy use (Madsen and Gram-Hanssen, 2017).

The sensory lens focuses on the interaction between the material environment and people, and between people (Pink et al., 2013). In recent years there has been a growing interest in sensory experience in several disciplines, referred to as a "sensual revolution" (Bull and Howes 2016), or a "sensual turn" (Howes, 2003, p.29). A growing body of literature has examined sensory experience, and application of the sensory lens has expanded from architecture (e.g. (Holl, Pallasmaa and Pérez-Gómez, 1994), (Pallasmaa, 2005)) psychology, physiology (e.g. Breslin and Huang, 2006), phenomenology (e.g. Merleau-Ponty, 1964) and anthropology (e.g. Howes, 2003, p. 29-58) to marketing and consumer research (e.g. Valtonen, Markuksela and Moisander, 2010), in humanities, social sciences and arts (Howes, 2003, p. xii-xxiii). Recently, domestic energy use has been studied through the lens of sensory ethnography in the UK-based LEEDR project (Buswell, Webb and Mitchell, 2015), and in the Australian project on automated smart homes (Pink et al. 2016). Sensory ethnography is a method which "attends the sensory experience, sensory perception, and sensory categories of experiences and everyday life. Sensory ethnography puts the sensory, experiential and affective elements of lived reality to the forefront of research design, conduct, analysis and representation" (Pink, 2015, p. 4-8). By observing and modelling everyday practices at homes, researchers were able to understand how people make their homes 'feel right', and how they need to use energy to do this. Understanding everyday practices in the home reveals what constitutes energy demand, and what are the residents' goals and values.

2.4 Sensory User Experience

The concept 'user experience' (UX) is widely used in HCI, though there are many definitions and views of what it means (Law et al., 2008; Rajanen et al., 2017). In the ISO standard 9241-210 UX is defined as "person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service" (ISO DIS 9241-210, 2010). We understand UX as the interaction between a user(s) and a technology, in a broader context of use, including diverse aspects of the users' mental states, perception, feelings and other sensations before, during and after the interaction of interest. We use the concept "sensory user experience" to describe the overall context of and interaction with a technology, from the point of view of sensing, making sense of, and using and feeling the space where the technology is placed. We investigate sensory user experience, i.e. sensory experiences and sensory aspects of practices, meanings and values related to energy use and the use of SHEMS. Sensory user experience describes what sensory needs and preferences users have related to SHEMS, how the use of SHEMS feels, and what sensory implications the use, or the absence of use of SHEMS brings.

3 Research design

We conducted a sensory ethnographic intervention as a part of a value-sensitive design process. Value-sensitive design (VSD) is a framework for identifying key values, value priorities, value conflicts, barriers to implement values and to design for values (Friedman, Hendry and Borning, 2002; 2017). VSD proposes a tripartite process for design: conceptual investigation, empirical investigation and technical investigation (Friedman, Kahn and Borning, 2002). This study is an empirical investigation, informing of the context in which the technology is situated (Friedman, Kahn and Borning, 2002). We chose to apply sensory ethnography as a lens in our VSD empirical investigation, as it gives an understanding beyond language level of the meanings energy usage in home carries, informing the future design of SHEMS. When sensory ethnography is applied to the study of user experience of a ubiquitous technology, attention is to be paid to (interconnected) senses hearing, seeing, tasting, touching and smelling the environment and other people, and moving in the place. The role of the researcher is to share the experience with participants and "be as loyal as possible to the context, the embodied, sensory and affective experiences, and the negotiations and intersubjectivities through which the knowledge was produced" (Pink, 2015). Sensory ethnography can be applied either as an independent study, or as a part of a research or design process (Pink, 2015). The analysis begins from the first contact with the research participants, therefore the researcher's experience and resulting understanding is more complete if s/he does transliteration and analysis her/himself.

This research was conducted in 21 Finnish families in fall 2018. The families were either new or experienced users of SHEMS, or had expressed their interest in having one (prospective users). New and prospective users were a self-selected group of households, who had contacted a local project for energy conservation through SHEMS. The project offered a possibility to acquire a SHEMS with project support (50% of the system price). At the time of research, new users were taking the SHEMS into use. Prospective users had been informed and discussed with about SHEMS, yet they had decided not to adopt it. Experienced users were from the group of first adopters of SHEMS in the project, and had used it for 2-4 years. Sensory ethnography study was part of the larger research on SHEMS use, therefore the need, use and/or experiences of SHEMS were implicitly on the background of this study as well. None of the research participants dropped off the research during or after the research. Table 1 shows the distribution and types of the households involved in this research.

Table 1. N=new users, E=experienced, or 1-4 years with SHEMS, P=prospective users, who are interested but have not acquired SHEMS yet.

Home	**Householders**
N1	Technical project manager, 46-50, Social worker, 41-45, 3 children under 18
N2	Social worker, 31-35, HVAC engineer, 31-35, 3 children under 18
N3	Medical doctor, 31-35, Medical doctor, 31-35, 2 children under 18
N4	Work coach, 56-60, School headmaster, 61-65
N5	Entrepreneur, 41-45, Entrepreneur, 41-45, Student 18-20, 3 children under 18
N6	Teacher, retired, 71-75, Teacher, retired, 71-75
N7	Entrepreneur, 56-60, Entrepreneur, retired, 56-60
N8	Nurse, 51-55, Nurse, 56-60
N9	Nurse, 36-40, Project manager, 50-55, 2 children under 18
N10	Entrepreneur, retired, 50-55, Entrepreneur, sick-leave, 50-55
N11	Accountant, 60-65, Nurse, 46-50
P12	Technical product manager, 40-45, Physiotherapist, 41-45, 2 children under 18
P13	Teacher, 41-45, Civil engineer, 41-45, 3 children under 18
P14	Project manager, 41-45, Teacher, 41-45, 2 children under 18
P15	Nurse, engineer, 41-45, Student, engineer, 41-45, 2 children under 18
E16	Telecom technician, 56-60
E17	Construction worker, 51-55, Social worker, 51-55
E18	Project manager, 51-55
E19	Real estate manager, 56-60, Public officer, 56-60
E20	Executive director, 56-60, Entrepreneur, 56-60
E21	Sales director, 41-45, Sales administrator, 41-45, 2 children under 18

We opted for mixed methods in our sensory ethnography study as proposed by Pink (2012; 2015), as diverse perspectives help to capture and illustrate the invisible and complex sensory user experience of SHEMS. The study consisted of three parts. The visited families were first interviewed on the values related to energy use and demand flexibility through smart home technologies and on their interest and use of energy and other home technologies. Second, they were asked to draw a mental map of their home and explain the places with most meaning for them, what are the meanings and sensations and why they are important. They were given a white paper and colour pencils. Third, a video-recorded tour around the house was conducted. The interviewees were asked to re-enact their morning, after-work and evening routines in the home. during which the informants re-enacted the daily routines and explained how they used each space in the home, and what meanings it carries for them. The re-enacted routines were video-recorded, and the mental map drawings scanned.

In this paper we analyse the experiences and sensory aspects of practices, meanings and values related to energy use and the use of SHEMS in the families, acknowledging also the sensory needs and preferences related to SHEMS, how the use of SHEMS feels, and what sensory implications the use, or the absence of use of SHEMS brings. In another publication (Tuomela, Iivari and Svento, 2020) we analyse the effects of the SHEMS to actual electricity consumption. The data analysis was a continuous process from the first encounter with the participants. The researcher video- and voice recorded and made notes during the interviews, and wrote transliterations right after them. The analysis of data and selection of relevant data for the description of sensory user experience was an iterative data-driven process, returning to the video recordings, the transliterations, home mind maps and notes. The sensory themes emerged from the material through repetition and emphasis in several interviews. The quotations, which illustrate the most common themes and categories were selected from the transliterations.

4 Results

The sensory lens we utilized enabled to identify the following findings: 1) home is a social and sensory place rather than a material one, and SHEMS plays a role in creating the sense of the home; 2) sensory user experience is to be approached as a social, negotiated, shared experience; 3) different parts of home impose different requirements for sensory user experience; and 4) various sensations such as warmth, view, scents, sounds and light are relevant in the sensory user experience of SHEMS. With quotations and selected mental maps of home we demonstrate that sensory user experience of SHEMS in homes consists of intertwined and overlapping sensory and affective sensations in physical, material and technological settings. The quotations are marked with a code N=new users, P=prospective users, E=experienced users, household number, and F=female or M=male, e.g. (P14F).

4.1 Home is where the family is

The sense of home is social rather than material, and the sense of home comes with other people. Home is where the family is together, and family members see, hear and feel the presence of each other. This was indicated not only in talk and drawn mental maps, but often the interviewees looked each other and smiled as they stated that. Family life is centred in a kitchen, or in a kitchen-living room if they were combined as a larger open space. Children come there to do homework or to play. In an open space people see and hear each other, even when doing their own things. People sense each other's presence and activities around the home and integrate their own activities accordingly.

In figure 1. the mother of the family symbolized the kitchen with a heart. Kitchen is a place where she enjoys cooking, socializing with family members, where everybody finds her, and she feels confident with what she is doing.

> "Kitchen is 'the home' for me. It is in the center, and I see and hear everyone there. I also see from the windows to the both sides of the house. The children know they always find me in the kitchen. I like to do things there, and it is always warm there. […] In the winter time we have fire in the reserving fireplace, and the heat and the sounds of fire make the kitchen very cosy." (P13F)

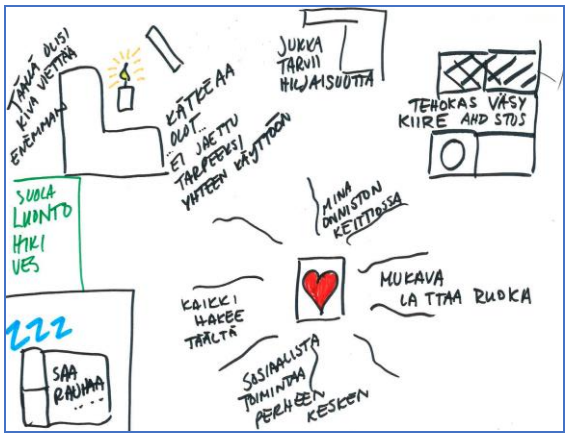


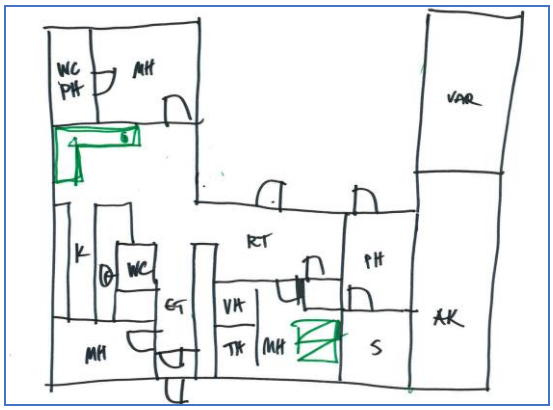
Figure 1. Mental map of home, female, teacher, 42 years (P13F).

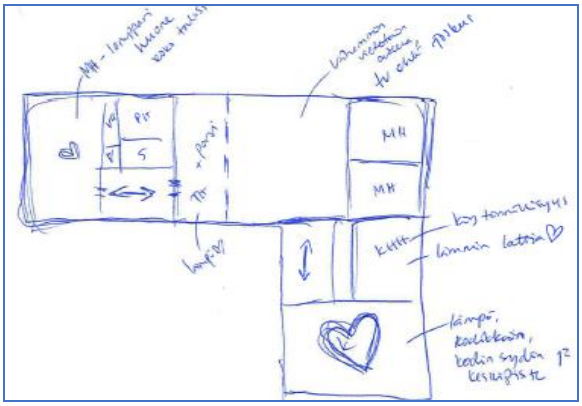
In figure 2 a man who lives with his wife and an adult child explains he spends most of the time on the couch (green spot), because there he has good view around the kitchen-living room and to the garden outside. Open space in the centre of the house in the company of other family members is more attractive than other rooms, which are considered too small, dark or too isolated.

> "This [the spot on the couch] is the cosiest place for me. […] When I sit here, I see here [the kitchen] and here [the dinner room and the hall] and I see very well outside, too. I watch the TV there, as well. And here the home life is around me. […] bedroom, there is no space to do anything else but sleep. Or well, if wanted, it could be a nice relaxing place, there is the window and the sunshine in the evening. Here [in the living room] we don't have the evening sun. […] All the light… well the morning is the best here, because the morning sun shines here [to the living room]. […] Here [kitchen – living room] we all usually spend all time except the night time. Even my daughter only goes to her room to sleep. […] I often work here in the living room. […] The work room is too small and tight."(E19M)

In figure 3. the mother of three children draw a heart in the kitchen and in the bedroom.

> "This is the heart of the home [kitchen]. I don't think we spend much time elsewhere. […] Even the bigger boys don't spend much time in their own rooms. They are so social they prefer to be where we others are. Even though they would be playing with mobile phones […] Here we are always, this is the center of the home. The wood stove heats, it is wonderful. […] I feel cold very easily, this is an old and drafty house." (N2F)





Figures 2 and 3.Mental maps of home, an engineer, male, 56 years (E19M) and a social worker, female, 36 years (N2F).

Most interviewees repeated the same idea with their own words.

> "Also for me this kitchen-living room is the center of the home, but I also enjoy pottering around in the garage and outside. Yet all starts always from the kitchen, wherever I head to." (P15M)

> "All things, paperwork and with computer, I do in the kitchen. The life is here." (N8F)

Empty-nesters, i.e. couples with adult children who have left the house, spend more time in the living room than families with children.

> "Our time together is always placed in the living room, often we even dine here. It feels home here, because we are comfortably on the couch, also animals [a dog and a cat] lie here with us. The computer and the TV, everything is here within reach. We only cook and feed the animals in the kitchen. Other rooms we use very little." (N11F)

In the kitchen-living room the feeling of home is the most intense. People do not want to compromise the comfort of that place:

> "For me these, the kitchen and the living room are 'the home'. There has to be warm enough, that's why I've written them in red. There we all spend most of our time. The children come and do their homework there, they don't do them in their own rooms." (P15F)

> "There is a warm atmosphere, both temperature and feeling." (N2F)

Hence, SHEMS is intertwined with creating this sense of home: it is involved in increasing comfort and wellbeing in this social core of home. The sensory experience that emerges in this social core, in the creation of which also SHEMS plays a part, is also strengthened due to presence of other family members, and often also due to other sources of sensory stimulus (e.g. cooking and eating, fire in a wood stove).

4.2 Negotiating shared sensory user experience

No matter where the centre of the home is, the wellbeing of the family is one of the key values in home. There are continuous negotiations between family members on how to guarantee wellbeing for everyone. Preferences differ when it comes to practices entailing energy use. Often social practices within a family are compromises of individual goals, needs and preferences. When practices are negotiated, the initiative may come from any family member. For example, one family gave up a second car, started to work remotely at home more than before, reconsidered how they shop, use the car and use energy, and is planning to acquire solar panels, after negotiations with their 'green' teenager.

The sensory user experience of SHEMS, thus, needs to be considered as a sensory user experience of a family, i.e. constituted by a person's own experience and by those of other family members. Sensory user experience of SHEMS, therefore, is often a shared user experience. In the interviewed families the main user of SHEMS was usually the man of the family. Nevertheless, often the couples decide together about the acquisition, as other decisions concerning money. In addition, how the system is used is negotiated in terms of comfort. In the families, where the male is the main user of the system, all adult family members have their say on the comfortable level of temperature. Even if only one family member actually interacts with the SHEMS, all family members give him feedback. Even inhabitants of the house, who are not able to give direct verbal feedback, such as children and pets, are taken into account in the sensory user experience. The house is kept warmer if there are small children, who are often at lower and colder level in a room. In addition, some did not want to decrease temperatures when people were absent, if there was a pet staying in home.

> "We don't usually lower the temperatures even if we are away for a holiday. We leave the cat here, and our [adult] children come every day to feed it…" (N8F)

Moreover, extended family members are regarded in the use of SHEMS. If a couple with adult children has them for a visit, the temperature is increased both for the comfort of the adult extended family members, and for the grandchildren, if there are some. For elderly visitors the home is adjusted as well. Extended family members are usually hosted in otherwise little used and therefore normally cooler bedrooms, and temperatures are raised during the visit.

Families also differ in the structure of their daily life. Retired people and shift workers don't have as much and as regularly time of absence from home, as do families with regular working and school or day care hours.

> "I work in shifts now, therefore we don't have 'all away' moments regularly. […]" (P15M)
>
> "I work mostly remotely from home […]. L. [wife] often spends time with the baby in the same room […]. We are always together at home. (N9M)

Family composition and the house plan, structure, materials, garden and numerous other house features determine what opportunities or limitations householders have for energy management, and how their daily sensory paths form. Home energy technologies are installed in a home with preconditions, ways of living and diverse needs.

> "We did not plan to move this far from the city, but we fell in love with this house. […] Now we have to have two cars for driving to work and heat a large house, which […] is not very environment-friendly. We live with these facts and try to compensate that with other ways." (N3M)

4.3 Different parts of home impose different requirements for sensory user experience

There are spaces in the home which are used very little, either because householders are regularly absent, or because they don't have a need or particular desire to use those spaces. Rooms which are not used much lack particular sensory feeling, and are often optimal spaces for reducing heating with SHEMS.

> "We are hardly ever in the smaller bedroom, it is like a walk-in closet for us. And the whole attic is only full of junk, we never spend time there." (N11M)

There are also places that are neutral or even unpleasant for some. A utility room is a place of "stuff I just have to do", a "technical place", especially for some women. Men do not mention it at all. SHEMS can be used to conserve energy according to the use of the space, and sensory experience may be improved e.g. with better heating and lighting.

> "The room with washing machine and tumble dryer is always full of things to do. I don't like the room, it does not have any windows. But I have to go there every day to resolve the mountains of washing to do." (P13F)

Spaces in the home are also used according to daily rhythms of family members. During the daytime people are mostly in the kitchen and in the living room (if next to the kitchen). Night-time should be calm and cool. Families spend very little time in bedrooms during the day. Only two interviewees, who lived alone, watched TV in the bedroom. Others preferred to keep the bedroom free from any activities but sleeping. Hence, bedroom is preferred cooler than kitchen, except for the moments before and after sleeping. People want to change clothes and stand with bare feet in a warm bedroom.

> "I try to set the temperature at home in such a way my wife's toes do not feel cold […] We like to sleep in a cool bedroom, but in the morning it is nice to put feet on the warm floor." (N6M)
>
> "We have three bedrooms here, and we use only one. […] we could lower temperature in two of them, but if we keep all doors open, does the thermostat of the warmer bedroom heat also two others, does it make any difference?" (N8F)

Sauna is a place of relaxation, especially for men. Though electric sauna consumes a lot of energy when heated, the importance of sensory aspects of going to sauna surpass frugality. People with a separate sauna building with a wood heater (kiuas) prefer to use it rather than an electric sauna in the house, but rather for sensory than economic reasons.

> "Why we call this home…the sauna is the major factor why this feels like home." (N3M)
>
> "Certain things we want always have available for use, like sauna, warm water, the dishing machine and the washing machine." (N10F)
>
> "Sauna is for relaxing…the dim light, scent of wood, warmth, humidity and the sound of heater as I pour water to it make me forget all worries." (P13F)

Home is not only a house, but also the surroundings of it. The yard and garden around the house were mentioned by many householders emphasizing the importance of extended space. Some men do things daily in the garage or workroom. Therefore, SHEMS may be used also in other but main building.

> "After the dinner… we often pass time in the garage with my son doing things." (N1M)

4.4 Variety of sensations involved in sensory user experiences

As already pointed out, there are many sensations people relate to the use of energy and that are associated with SHEMS. Warmth is an issue to be considered taking the entire family into account. Comfortable temperature is not compromised in the home spaces which carry most meanings for people. Finding comfortable temperature is a way of caring of others. Many families stated female adults feel more easily cold than males. Therefore, temperatures are compromises which satisfy the needs of every family member. Warmth can also be a way of pampering:

> "The princess has a warmer room than her three brothers" (N5M).

As for sounds, disturbing ones were identified. Though the use of the washing machine could be more economic and more ecologic during the night hours, the noise it makes is disturbing. Some families had bought a very silent washing machine because they wanted to use it in the night-time when the electricity is cheaper. Homes with air heat pumps or with external radiators in bedrooms marked disturbing noises with SHEMS. When the system automatically seeks the optimal temperature and adjusts the heating level, it causes air heat pump and radiators to make clicking sounds. If the heating systems were managed manually, there would not be surprising sounds in the night.

As for light, the way windows let light enter rooms and spaces impacts their use. In the bedroom sunrise or sunset is appreciated, but not direct midday sun. Too dark room does not invite householders to spend time there. Children sometimes prefer to have a dim night light in a bedroom, or outside, for not feeling scared when waking up in the night.

As for view, people prefer to spend time in places with a good view both to outside and in the main space in home, i.e. usually kitchen-living room. Especially men, who seem to prefer to sit on the couch or in the armchair, choose such a place and direction they can see well both outside (preferably the garden or the riverside) and to the open kitchen-living room space.

> "This living room is an important part of the house. Here we relax in the evenings watching TV, and also the view to the river shore is very relaxing." (N11M)

> "There in the kitchen - living room is the center of home, there we watch TV and it is easy to depart everywhere. In the winter time we feed birds and enjoy watching them out the window." (N7M)

> "There is a very comfortable armchair in the living room, it makes me fall asleep easily […] There I can see well outside […] I can sit there and watch R. [wife] doing things in the garden." (N6M)

The role of light, view, scents and sounds are components of sensory experience in different spaces and they contribute to requirements for SHEMS, and also offer opportunities for improvement of sensory experience through SHEMS. For example in a place, where householders enjoy together evening sunset light heating can be automatized higher for those hours, and in turn other rooms may be cooler during the absence of people.

The use of firewood is a good example of variety of sensations intermingled with each other. The use of firewood has many meanings. Even if the main heating system in all homes was electric, most interviewed families have a fireplace or a wood stove, and they use it in the winter every 2-3 days to heat the house. The wood stove is usually placed in kitchen-living room, and it was used in the winter heating season to reduce the need for electric heating, but also for sensory effects. The wood stove gives out 'soft' heat, that is not experienced as dry as electric heating. Also, the sounds and scents of burning wood add to the 'feeling of home'. Carrying and keeping logs indoors gives out smell of wood. The wood stove can also be used for cooking. Though that possibility was used only by two of the interviewees, the idea of cooking on a wood stove underlines the idea of a home. The ritual of cut-

ting wood and reserving it for the winter is part of the traditional and self-contained way of living in Finland. The people who use wood stove for heating usually get wood from their own or family forest. Homeowner's forest ownership increases the utility, and probability to use solid wood fired heating (Rouvinen and Matero, 2013). The quotations below indicate people do not only calculate reduced electricity use when it comes to use of wood, therefore substituting heating with wood with other heating methods and automation is not straightforward.

”Wood releases heat which is much softer and more pleasant than electric heating gives.” (P14M)

”The smell of wood and burning wood is cosy.” (P12M)

”A warm wood stove in the kitchen is the heart of home.” (N4F)

”Burning fire is calming to watch.” (N10F)

”Burning wood crackles and creates a warm atmosphere.” (E16M)

Abovementioned elements of sensory experience were surprisingly similar in all families, and in all three user groups of SHEMS (experienced, new and prospective users). What differed between the user groups was the perspective on the relationship between sensory user experience and SHEMS. New users were hoping their sensory experience would improve due to the use of SHEMS, yet cautious not to sacrifice the feeling of home and other sensory values with the use of SHEMS. Experienced users felt their sensory user experience had improved, as the system had learnt and optimized its functioning during the years they had used the SHEMS. Prospective users were hesitant to acquire SHEMS, because they were unsure if it would improve or weaken their sensory experience of home. Naturally also other factors, such as the estimated return on investment, influenced the decision to acquire and use SHEMS as well.

5 Discussion

In this paper we conceptualized the sensory user experience and studied the sensory user experience of SHEMS and the feeling of home to extrapolate implications for future research and design of smart home energy technologies and services. We enhance the research of sustainable digital practices in IS with more profound understandings of the condition of humans interacting with ubiquitous and pervasive technology, as called by Bødker (2014) and Yoo (2010).

Based on our study we have brought into light how the sensory user experience of SHEMS is composed by the sensory and social factors in home. Home is social and sensory user environment of SHEMS. Sensory experiences are heightened in social space, and social sets requirements for negotiations concerning sensory experience. Sensory experience and social environment and dynamics impact the use of SHEMS, and on the other hand the use of SHEMS shapes the sensory and social experience in home. This reciprocal relation between the sensory user experience and the use of SHEMS is important to acknowledge in the design of future SHEMS. Direct interaction with the SHEMS user interface constitutes only a fraction of the sensory user experience, and the direct interaction is desirable to diminish or even vanish with a smart system. Therefore, the user experience is necessarily the lived, shared sensory experience of people influenced by the system. Our example of the sensory user experience of SHEMS illustrates the complex nature of what Yoo (2010) calls ‘experiential computing’.

This study contributes to IS research on ecological sustainability in the context of home. So far studies in this context have neglected the intricate and complex character of this context (see Corbett & El Idrissi 2017, Kroll et al. 2019, Lossin et al. 2016, Shevchuk et al. 2019). This study pinpoints to IS research that home is more than a built physical dwelling, it is a sensation of socially created atmosphere. Home is where other family members are seen, heard and touched, and where they eat, relax, and do other activities together. Yet in a building where home takes place, not all spaces are equally ‘homey’, nor is home life equally active every hour a day. That leaves opportunities for energy conservation, demand flexibility and energy exchange through SHEMS. Understanding human-environment interaction in home allows the resulting design to support and enhance the sensory user

experience and increase the participation of homes in the energy transition. In decisions concerning home practices entailing energy use money is only one factor besides sensory and social ones. Even drastic changes in the price of electricity may not change consumption significantly (Aune, 2007). Our results are aligned with the results of sensory ethnography study LEEDR (Buswell, 2015; Buswell, Webb and Mitchell, 2015). Seemingly mundane everyday practices and sensory meanings are pivotal in how the user experience of home technologies evolves. Sensory ethnography as a lens provides researchers and designers of SHEMS with understanding of the use context and user values.

In Figure 4. we illustrate the elements of the sensory user experience of SHEMS, which consists of several factors related to the users, home, technology, and also to the larger context of smart grid and external factors influencing the energy supply and need. The scale of the elements of the sensory user experience is therefore much wider than only the direct interaction with the user interface of any SHEMS application. Energyscape is, following Appadurai's (1990) theory of scapes, the disjunction of material, cultural, economic, technical and political components, which is perceived differently by different kinds of actors and which questions the traditional models of center-periphery, consumer-producers and push-pull (Käkönen and Kaisti, 2012; Strauss, Rupp and Love, 2013, p. 22, 110). Sensory user experience of SHEMS is an experience in the home, but also in the wider 'energyscape'. This complicates the analysis and the design of the sensory user experience of SHEMS, yet understanding it is necessary for increasing the adoption of solutions which increase the use of renewable energy, energy conservation and support sustainable living.

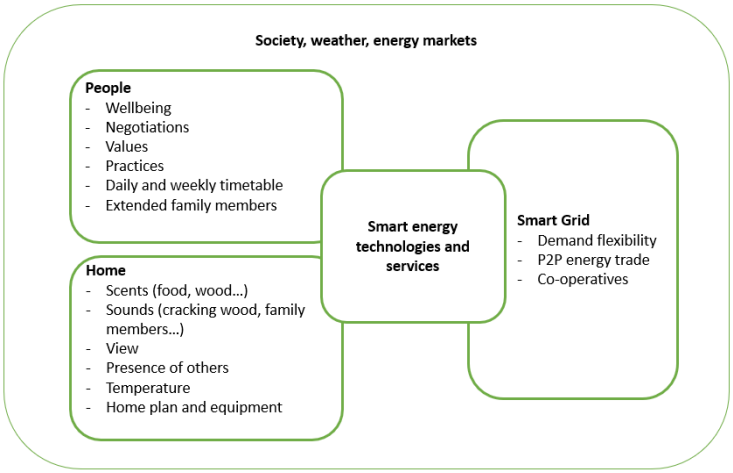


Figure 4. Elements of the sensory user experience of SHEMS.

Along with the growing interest in sensory experience, referred to as a "sensual revolution" (Bull and Howes 2016), or a "sensual turn" (Howes, 2003, p.29), this study introduces to IS research sensory ethnography as a method which "puts the sensory, experiential and affective elements of lived reality to the forefront of research design, conduct, analysis and representation" (Pink, 2015, p. 4-8). Other, methods, such as interviews, surveys and quantitative consumption data studies, give light about the use of SHEMS and other smart home technologies as well, but this study maintains that sensory ethnography is an advantageous approach in studying user experience of SHEMS. Mixed methods (home tour, mental maps, interviews) illuminate the studied phenomenon differently confirming findings. Researchers gain a rich understanding of the values and sensory, material and social aspects related to energy use and technologies, and implications for design of home technologies. However, there are challenges involved with conducting sensory ethnography. For example, verbalizing sensory and material aspects is challenging – also for the researcher. Sensory ethnography involves the researcher into the sensory experience together with interviewees, and the primary data includes text, but is beyond it. Recording, analysing and sharing multisensorial experience with research community is challenging. Transcribing the interview material reduces the sensory experience into text. How to enrich the analysis of sensory ethnography interview with the sensory experience, gestures, and even power relations of the situation? Different forms of transcription have been proposed, e.g. formatting the text to ex-

press tones, pauses and gestures, or multimodality (O'Dell and Willim, 2013. In addition to photos, pictures or cartoons can be used to illustrate and share the research data by seeing rather than reading, yet that emphasizes already dominant visual aspect and leaves much of the multisensory experience unattainable. Moreover, analysing video-recordings and other visual or sensory material is onerous and time-consuming, still participation of the researchers in transcription and analysis of data is worthwhile because the analysis in effect begins from the first contact with participants.

This study approached a topic of energy consumption in homes that has significant global consequences. Global challenges may require crossing or shifting the border between public and private (Berglund, Hage and Söderholm, 2010; Lundmark, Matti, and Michanek 2010). However, though most people acknowledge the need for the whole society to change energy consumption for common good, in the decision-making and negotiation own family and home come first. Immediate and easily identified changes in the feeling of home weigh more than more abstract and distant results of energy behaviour change (Moussaoui and Desrichard, 2016). Then again, it is expected that homes become prosumers and approach smart grid through SHEMS for selling their own energy production, storage, or participate the 'energyscape' in other active ways, raising many issues and questions for future research.

6 Conclusion

In our paper we have provided new insights on the sensory user experience of energy use in relation to SHEMS. We show what people consider important in their home and related to energy use, and which elements of the sensory experience they are not willing to compromise. Based on the application of sensory lens to energy use, the sensory user experience of SHEMS consists of interaction between family members, householders' interaction with energy technologies, and lived rich sensory feeling of home. People express their values in the way they live and in the decisions they make in home, as there is the most precious and intimate part of people's life. Home is private, and well-being and comfort of all family members is a priority, rather than a common, society-wide good.

Sensory user experiences in the sense introduced in this paper are significant topic of study also in other smart environments with ubiquitous technologies. Our conceptualization of sensory user experience provides opportunities to bring to the fore new thinking about the sensory, human-environment interaction and sustainability, so that we can better understand how to design systems that engage the people in the energy transition.

Our findings are of interest also for the designers of SHEMS, for planning of smart grids, and for policy makers who need to understand the user experience of home energy technologies, and what people value in their home. This study has gone some way towards enhancing our understanding of the sensory user experience of a ubiquitous system in the home context. Our conceptualization and approach can be applied to diverse contexts to reveal sensory dimensions in socio-technical systems.

This study is limited to families in the Northern Finland (except for two families in the capital area). They all live in a detached house in suburban area or in a small municipal close to a city. They all are new, experienced or potential users of SHEMS. Therefore, more research is needed to generalize the results to different circumstances and interviewees.

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