Probing a Proactive Home: Challenges in Researching and Designing Everyday Smart Environments

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Abstract

Based on the results from a three-year interdisciplinary study, this article introduces the development where proactive information technology is becoming introduced into future homes, and provides human-centred research into its acceptability and related design principles. As intelligent technology, the discussed application of proactive computing in homes will face particularly sensitive conditions in homes, where familiar and reliable home elements are strongly preferred. The article will evaluate a cross-disciplinary methodology that has been developed to assess not only the contemporary expectations and attitudes towards smart homes, but also people's experiences derived from living with variously designed experience prototypes installed in their homes. One of the key outcomes is that both the calm system behaviours and the degree of variety in aesthetic designs will play major roles in the acceptance of proactive technology, as proactive technology will be an embedded part of home's structures and furniture, and thereby needs to blend with the normal, cosy standards of real living environment.

1. Introduction: Changing Ecologies in Homes

> In a way, it could be quite a nice idea that there would be coffee ready and waiting when you wake up, lights would be automatically switched on – but on the other hand, there is a certain enjoyment in doing it yourself, closing the curtains, lowering the Venetian blinds and switching off all the contraptions. And in a way, when you think about it, I have no need for any change. (M, 35. *All informant quotes translated from Finnish by the authors*.)

Modern homes are becoming increasingly saturated by various technologies, ranging from new generation of kitchen utensils and domestic appliances, and concluding to home computers, digital televisions and wireless media servers. The sales of consumer electronics appear to rise into record heights every year (see *www.ce.org*). One vision of future that is repeatedly evoked by industry in particular, is *smart home* as a new kind of technologically enhanced living environment. There are different versions of what "smartness" means in this context, though, depending on whom you ask. Planning a home around a complex entertainment centre may be smart for some, whereas others emphasise home security systems, or even more ambitious "home automation" solutions, where numerous home elements like lighting, door locks or window shades are programmed to behave in certain ways.

Home automation is not yet reality in most homes, not even in the technological West, and there is also some resistance towards the whole idea, like the above quote illustrates. It can actually be questioned whether there exists a real need, for which a smart home (as it is currently marketed) would be a solution. The issue should be approached from a different angle: it appears that we are already living in relationship with different devices and technologies where our living is shaped by them, while we also make decisions and apply these technologies in a way that shapes their value and usefulness. This kind of interdependent connections, and networks they form can be conceptualized as *ecologies*: an ecology is traditionally defined as a study of organisms and their environments, but as the concept has revealed its usefulness also beyond the field of biology, there has emerged research into community ecologies, information ecologies and media ecologies, among others. For example, Nardi and O'Day define information ecology as "a system of people, practices, values, and technologies in a particular local environment". They emphasise that the actual spotlight when studying information ecologies is not so much on technology in itself, as it is on human activities that are served by technology. (Nardi & O'Day 1999, 49.)

The main argument in this paper is that we need to develop a multidisciplinary approach to study our increasingly intensive and intimate relationship with technology. It is insufficient to regard people who are adopting or rejecting new technologies just as passive consumers, since their attitudes and practices are having a powerful effect on the success or failure of particular devices or services. But it would also be a failure to miss out the important ways in which the design, distribution and marketing of new technologies are having an effect on the relationship. As the research and development practices are becoming more closely informed by user studies, the opposition of production and consumption that was typical for an industrial society is giving room for various practices and negotiations taking place around the activities of co-design and co-production, which are increasingly typical in a post-industrial society.

The original starting point of our research was the need to provide a human-centred view on the development of proactive technologies in homes. "Proactive" technology is related to a particular, information technology industry driven vision of future, where omnipresent computing, sensor and other technologies have been developed to the point where they anticipate our needs and act on our behalf (Tennenhouse 2000; Want, Pering & Tennenhouse 2003). There are obvious commercial reasons for companies like Intel and IBM to focus on such processor-saturated view of the future, but when raised to the agenda of researchers and developers, such visions may also carry some self-realizing power. It was our aim to confront the concept of proactive computing, adapt it into the concrete local environments in real homes, and thereby produce better understanding about the related acceptability, usability and feasibility issues, if such technologies would indeed adopted and installed in future homes. In this way, our research is both a contribution to the critical science and technology studies, as well as a call for more ethically sustainable ways of developing new home technology.

There are actually certain reasons why we might have need for such technologies in the future. It is sometimes claimed that primarily the aging of population will necessitate the development of smart home environments, but as we argued in our book *The Metamorphosis of Home* (Mäyrä & Koskinen 2005), there are serious ethical considerations that have to be taken into account if human contact, independence and autonomy are becoming replaced by technology acting proactively, rather than just developing assisting technology, where humans themselves take action in their lives and work. We claim that the possibly most crucial need for proactive technologies in homes will be related with the logic of information ecologies themselves and with their evolution. It is already becoming observable reality and common problem that the omnipresent media and communication technologies are also creating stress and increasing the complexity of life rather than just helping us to cope. As information network connections are becoming prevalent in such ubiquitous devices as televisions, stereo systems and games consoles, as well as in mobile phones and cars, there will also be related surge in email, instant messaging and other information, much of it likely unsolicited messages ("spam") or otherwise undesirable information, and the overall cognitive load is must be taken into account in every context. Effectively, our information ecologies are rapidly becoming over-saturated and the proactive technologies will be perhaps most urgently needed to control and supervise all the other technologies that are fighting for the limited resources of our time and attention. Our starting point for proactive home technology design was that, if adopted, these technologies should primarily be developed to enhance the '*homeness*' of homes: to support and protect those qualities which are central for people in their homes, including peace, relaxation, intimate human relationships, and shelter from pressures of modern life.

This article will also look for some preliminary answers to the questions like what are the design principles for how proactive technology should be built and implemented in future homes, but it is even more focused on the fundamental research issue: how can we develop a *human-centred methodology* for researching a technology that has not yet been fully implemented by industry or adopted to use? It describes how we developed an interdisciplinary approach where researchers having different backgrounds in the study of user cultures, design research, and technology research and development joined their forces in an iterative process of inquiry, design and evaluation. Since our approach involved interventions into real homes, where we introduced a prototype design of new home element into an existing home ecology, our approach has also similarities with action research. In his 1970 paper, Rapaport claimed that action research "aims to contribute *both* to the practical concerns of people in an immediate problematic situation, and to the goals of social science by joint collaboration within a mutually acceptable ethical framework". There are numerous practical issues related to the approach we adopted that will be discussed below. In a wider perspective, our research was designed to combine all three key knowledge interests as identified by Habermas in his *Knowledge and Human Interests* (1972):

- technological (providing solutions for new & innovative uses of the potentials of emerging technologies)
- hermeneutical (aiming at mutual understanding)

- critical (aiming at the disclosure of errors in our systems).

This wide coverage of interests was only achievable with the help of broad-based interdisciplinary collaboration.

Our research project was titled as “Living in Metamorphosis: Control and Awareness in a Proactive Home Environment” (Morphome), and it was devised and carried out in close collaboration between three universities: University of Tampere, Technical University of Tampere and University of Art and Design Helsinki. The original research question was focused on investigating how “distributed, non-intrusive access and input” could be designed and implemented so that it facilitates adaptive control and awareness in a proactive home environment. But as the work progressed, we gradually moved into exploring what are the key design principles when developing proactive technologies that are felt appropriate and acceptable in domestic environment but also interesting in their design. The methodological challenge remained as a constant concern as we approached the issue of engaging into human-centred research of future home technologies.

There was some previous research that offered models for the main alternative directions into studying smart homes. The key issues were related into the role of control, and how human agency is being defined in the human–smart home relationship which is at the heart of the “home automation”:

1. User is in Control (most tasks are consciously triggered)
2. Home is in Control (most tasks are automatic)
3. Learning Models (a. user is adapting to principles of environment; b. environment tries to learn and adapt to the user)

(See Edwards & Grinter 2001; Intille et al. 2002; Harper et al. 2003.)

It should be noted that all of these relationships are reciprocal, and highlight the symbiotic relationship we have with our environment. We are not only following the line of study of “situated actions” (Suchman 1987), but rather looking into technologically co-determined actions and relationships in a situation where technology itself is starting to exhibit adaptive, reactive and proactive (“intelligent”) traits.

We will first discuss our methodology, then how it was implemented in the different phases of research, present derived results and finally discuss the lessons from the entire, three-year research process.

2. The Interdisciplinary Methodology

We have above briefly mentioned the overall interdisciplinary character of our research, and how it intersects and combines both human sciences (hypermedia research), design research (industrial design) and research of information technology (personal electronics). Since the phenomenon of powerful and intelligent computing technologies cohabiting homes with their human occupants is still mostly in a potential future, our approach could not only be focusing on a methodology that describes and analyses existing user behaviour. Yet, the research group wanted to understand how the functioning of proactive or somehow autonomous technologies would be experienced and approached by informants as a part of their actual living environments, and that meant implementation of some kind of prototype systems, at least up to the point where an experience of features relevant for the research questions would be achieved. In the design research field, this approach is called *experience prototyping* (Buchenau & Suri 2000).

We posit our work at the cross-section of three perspectives, where practical, applied and theoretical interests take the form of three intersecting viewpoints: technology-potential oriented, human-interest oriented and design research oriented. The research is also dividable into different phases or dimensions in terms of the research process phases and their relation to application and implementation. Thus, the descriptive part of *user study* aimed to gather information that would help us to define how our informants understand ‘home’ in the first place, and what is their relationship to technology. From an applied angle, the results of this study could then be used as a background research data to guide the design principles for a use scenarios or prototypes that were created and tested in the next phase of the research. We used both *scenario studies*, where possible use situations of proactive home technologies were illustrated to our informants, and *prototype studies* which required construction of functional implementations. Prototype studies consisted themselves of research both into the design and technologies suitable for researching proactive technologies in homes, and also concluded with another user study, where user informants were interacting within a home environment modified by our prototype design. The hermeneutical circle was closed as the analysis of the results from prototype study was providing inspiration and data for new designs, prototypes and user studies.

The data gathered in the user studies has been analysed in a qualitative way. The aim has been to understand the diverse elements affecting people’s attitudes to proactive computing for home environments. It should be noted that the number of informants in prototype studies has varied from two homes to twelve homes in the different phases of research. Our informants were Finnish people of varying ages from children under school age to working people around sixty years old. They represented different compositions of households and almost all of them were living in a block of flats in Tampere or Helsinki. The results from these descriptive user studies should not be read as giving statistical information about Finnish people’s attitudes to new domestic technology. Rather they should be construed as the researchers’ interpretation about the participants’ adopted and to some extent unquestioned stances towards their homes as technological environment in the context of contemporary and forthcoming technologies.

The progress of the research and the different phases where the research methodology was implemented can be listed in the following steps:
1. collection of pre-understanding, setting of research questions
2. domestic probes study
3. formulation of the first design principles
4. the first design experiment implemented: the cushion study
5. formulation of new principles, as drivers for design and technology implementation
6. first implemented as scenarios of future homes, evaluated with interviews
7. new technology and experience prototypes implemented: light and sound design chosen as the focus of experiment
8. conclusions and a revised set of design principles created.

Each design phase also included its own internal phases of hypothesis setting, prototype design, implementation, testing and revision of hypothesis. One practical challenge in working with future technologies has been that such key terms as ‘proactive’, ‘ubiquitous’ or ‘context-aware computing’ are mostly intangible and unfamiliar for people not working with new computing technology, and concretizing them was a challenging task. The scenarios and experience prototypes have worked in our project as tools giving an illustrating or a concrete idea about potential applications to be used in the home environment in near future. The scenarios and prototypes were also used as a means to get people accustomed with the ideas and potentials of novel technologies. Although the attitudes emerging with scenarios and prototype testing do not equate with living constantly with ‘proactive’ technology they make people more aware of their existing domestic environment and technology it already includes. For instance, the existing devices, furniture and other objects were considered in a new light when product concepts were ‘brought in the home’ by means of scenarios and prototypes.

The participants remarked also themselves that it is difficult to imagine living in a home surrounded by proactive technology. Probably this difficulty relates to the nature of home as a place in which many habits are often carried out in a distracted or routine manner. Thus it can be challenging to assess consequences of new technology to domestic practices or way of living because dwellers are not necessarily so aware of their everyday activities and the role of technology in them. However, scenarios and prototypes can make domestic routines and embedded or underlying values more visible when people consider why they do not accept this technology while they are willing to try out that the other one. Thus giving an illustrating idea or personal experience of new technology does not work just as an inspiration for discussions but it can enable people to come more aware of their domestic habits and chores.

Because home is so familiar and taken-for-granted environment it can be beneficial to give people ‘tools’ that enable them to see their own home ‘in new eyes’. The prototypes can used as a means to introduce something ambiguous or strange into the familiar everyday environment. Gaver & al. consider *ambiguity* as a resource for design that can be used to evoke personal and interpretative relationships with technologies. They describe ambiguity as a property of interpretative relationship between people and artefacts that require people to participate in making meaning. One idea is that such designs encourage people to question the presumptions they have about technological genres but also to spur people to imagine how they might personally use and appropriate these artefacts and what their everyday lives would be like in consequence. Bell & al. (2005) call a fairly similar approach as *defamiliarization*. Defamiliarization has been originally introduced as a literary technique that has then been utilized in design processes as a tool that calls into question conventional interpretations of everyday objects. The aim is to outline those cultural, political and familial assumptions that are often built into domestic technology designs that also simultaneously constrain the design space. Thus examining these assumptions can open new and more reflected directions to design. (Bell & al. 2005).

As applied in our studies, the aim of defamiliarization and ambiguity was to elicit people to reflect on their perceptions that seem natural and self-evident in the context of domestic technologies. Discussing people with their experiences in an ‘estranged’ home environment provides designers and researchers with the opportunity to consider the existing cultures of home life and to develop new alternatives to domestic technology design The participants felt their home more or less strange when testing our prototypes like decibel lamps or the automated home system because changing the ecology of home this way made some aspects of domestic life more visible than before. As technological genres the decibel lamps were not unequivocal. Visualization of auditory information was a new experience that made the participants more aware of the soundscape of home and its silent and loud moments. From their design some of the lamps were easily recognisable as ordinary table lamps (either modern or retro style) whereas some of them differed from conventional lamp design. The adapted home automation system increased the participants' awareness of movement in the home. Especially in the beginning of the test period the participants could feel as intrusive some features, such as snaps of the lamps based on motion sensors. Lights reacting to movements made the dwellers prominently aware of each others' walking in the space or changes of position while sitting on the sofa near to the test lamp. And to give a different example, the gradually growing sounds of sea we had used in the proactive wake-up sequence made our informants conscious of what kind of effect typical bleeps of alarm clocks or voices of certain radio channel have in their feelings during the waking up. It also got them to ideate alternative ways for waking up or going to bed in the evening.

3. Case Studies into Home Technologies

3.1. Domestic Probes and the Cushion Study

The starting point for the first research phase was the realisation of how complex social and material environments homes really are. There are multiple private and public dimensions of significance that home can have for a person, and there is an increasingly complex network of meaningful relations overlaying that, when several people are sharing and inhabiting same space. To produce qualitatively driven data that would also be suitable to inspire our design research in concept search, we applied a design research approach called *cultural probes.* Originally created by Tony Dunne and Bill Gaver at Royal College of Art (see Dunne & Pacenti 1999), the cultural probes method is a tool that facilitates user creativity and the practise and philosophy of co-design, rather than just treating informants as sources for knowledge the researcher is only able to derive. We devised a group of self-documentation tasks, materials and the accompanying instructions to provide our informants with a rich set of tools to explore meanings, values and emotions they relate to their home, and technology it contains. As we were interested both in producing qualitative understanding about peoples relationship to homes and home technologies, as well as deriving starting points for future proactive technology designs, we modified the original probes method. When the probes were returned from homes, they were analysed and reflected upon both in design workshops among the research group, but also in group interviews where the interpretations were discussed with the informants themselves.

The central outcome was a better understanding of how sensitive quality the 'homeness' of homes is; it is produced by daily actions, memories and affective relationships, and at the material level is related to familiar objects and to their placement in spatial order of home interiors. The "psycho-geographic maps" that probes method revealed as invisibly surrounding home technologies can be rather complex (see below, Figure 2). Another key finding was the relationships to technologies were often ambiguous: not only choice and taste, but also necessity, household compositions and compromises among household members were dictating the presence of some devices. It also became clear that it is misleading to speak about the domestic technology in the singular because there are hierarchies and different roles among domestic technologies. Media technologies were felt as ‘proper’ technology while kitchen and bathroom appliances were regarded more as fittings of those rooms than technology as such. This can be explained by the different presumptions and experiences that people associate with these technologies. Domestic appliances are often perceived as simple devices that one can use without effort and manuals although many of them involve complex electronic and digital controls. People also expect that these stand-alone appliances do not crash (like computing systems) and this reliability has enabled them to forget these technologies as complex entities (Edwards & Grinter 2001). Furthermore, these differences relate to the stereotypical notions about ‘white goods’ as feminine and ‘brown goods’ as masculine. As time-saving technologies related to domestic work and personal hygiene white goods traditionally imply cleanness, simplicity, transparency and utility. Instead brown goods are for leisure and entertainment and they seem to signify complexity, cleverness, opacity and rich content. (Cockburn & Ormrod 1993, 100-104.) (See the chapters by Ilpo Koskinen, Katja Battarbee, Anne Soronen and Olli Sotamaa in Koskinen & Mäyrä 2005.)

Figures 1 & 2: The domestic probes package and a floor plan drawn by an informant, where the affective characters of home technologies are revealed with the help of animal figures.

Because its elusiveness the experience of domestic atmosphere is challenging to study empirically (e.g. Pennartz 1999). It was a common situation in the interviews that people had no words for describing relevant elements of domestic atmosphere but the tasks of the probes package made it easier to approach. By means of the probes kit people could concretize and illustrate which aspects produced ‘homeness’ in their own home. Tasks also encouraged people to consider both personal and familial significance of domestic technologies and their uses. Thus, they illuminated shared and personal meanings around domestic environment. Further, the probes made people to question some taken-for-granted aspects of domestic life or technologies. In this respect they also opened up new ways to us as researchers not only to perceive the domestic technologies in their existing contexts but also to ideate promising directions that proactive technology could take in order to support cosy ambience and sociality at home.

While the probes study was underway and the understanding of homes was getting deeper and more many-dimensional, the first prototype study phase was started. One of the first concepts that we decided to take further and test was technology in the shape of pillows or cushions. As we have also pointed out in *The Metamorphosis of Home* (Mäyrä & Koskinen 2005), pillows and cushions are intimate and personal elements, ubiquitous in homes and in their softness they also appear to be situated mentally at the opposite end from the stereotypical conceptions of “hi-tech home of the future” we were interested in challenging. Rather than stressful and hard, cushions associate with comfort, relaxation and softness. On the other hand, many traditional “smart home” concepts rely on use of screens and other explicit interaction interfaces to facilitate the control of these complex environments. Based on our prestudy and probes investigation, the decision was made to take the design research into direction which would explore ambient and tangible interfaces. Cushions and pillows were perfect also from this perspective.

A technical prototype was implemented, which operated as a simple experience prototype of an embedded context-aware interface. This consisted of cushion fitted with hidden electronics: batteries, power supply, microcontroller, amplifier with voice input and output (loudspeaker) connected to a recording and playback circuit, and a serial (RS-232) transceiver. The last component was essential for the operation of RFID connection, that was used to provide the pillow crude means for sensing its surroundings. As soon as a RFID tag was within reader range, the embedded electronics emitted a pre-recorded sound. In the test setting the pillow was covered by (fake) animal fur, and the sounds imitated animal sounds. This was related to the hypothesis that the limited “intelligence” of test system would suit better the level of animal, rather than human-level intelligence, which the use of human voices for interaction would have suggested. The test users were provided with pea bags which hide the RFID tags, each of which had a different sound associated with it, when brought to the range of the reader hidden inside the cushion, along with a loose set of instructions to try out different ways of interacting with the cushions, and with a video camera to record the run of events.

There were some technical issues in the testing which limited the range of RFID reader, and it was not possible to combine sounds in the flexible manner as was intended, but some basic interaction with this “special cushion” was possible. The main finding from the testing in real homes was that integrating interactions with smart home technologies are indeed going to be perceived in positively affective context if embedded in familiar and “soft” home elements like cushions or pillows.

The cushion was field-tested in three families with children and these informants appeared quite creative in their uses and ideas for further development for such technologies. When interviewed, the child informants suggested uses where a smart cushion would become the "emotional companion" for the occupants of their home. Such an interface for a smart home could comfort its user, provide companionship and access to house services while the occupant relaxes, hugging or leaning on the cushion while watching television or reading. In this sense, touch, proximity and sound provided rather natural and non-intrusive modalities for control and awareness in the shape of a cushion. The adult informants suggested that proactive system in general should provide services as a "secretary" or "manager" which would be of assistance to the family members in the challenges of organising their daily life. A network of different reminders, notes, calendar markings and mobile phone calls could be simplified if a smart home could offer itself as a helpful companion for this kind of uses.

Figure 3: A child informant experimenting with the cushion prototype.

After the probes and cushion studies, we had set up and collected some feedback from the initial set of proactive home technology design principles:

1. the principle of consistency: if a function or element is delegated to be controlled by proactive systems, that function or element should demonstrate similar behaviour consistently
2. the principle of personalization: smart home technology should follow the "rules of the house" that reflect practices and preferences adopted and followed by this particular individual or family in their private space
3. the principle of embedded media interface: the main goal and task for proactive technologies in homes is to provide filtering and control that negotiates the charged boundary between 'home-as-shelter' and needs for staying in contact with the 'world-out-there'

4. the design principle of animism for advanced proactive functions and services: the easiest and most natural way to interact with a proactive home would be to treat it as if it had some kind of persona or other social interface of its own
5. the principle of open-ended tangible designs, where proactive services are joined with physical objects which afford multimodal, sensory-rich interactions, will provide usable and aesthetically pleasing interactions for future homes.

(For a more detailed discussion, see Mäyrä & Koskinen 2005.)

There were two basic direction our research could have taken after the first phase; one where the focus would had been on interactions and co-habitation in a home augmented with “strongly proactive technology”, and the other direction following “weak” interpretation of proactivity. A strongly proactive home system operates in the background and completely without human awareness, combining input from various sensor systems, applying computation into the situation, and advancing from these into autonomous actions. As a human interface design research issue this was not as interesting case as the “weak” alternative which is a bit closer to the situation of interactive computing: the state and operations of smart technology need to be conveyed to the human occupant, and the system will notify the user, offer alternatives and give the choice of accepting and cancelling actions, rather than completely “removing the user from the loop”. This is not as efficient alternative if only the reduction of users’ cognitive load is being considered, but based on our interviews and other user studies, the human-supervised direction of smart home technologies was also considered as more acceptable and ethically sound than a directly moving into totally non-aware and autonomous operation of technology in homes.

The design of weakly proactive home technologies is related to the research into “calm technology”, as approached within the field of ubiquitous computing. (See Weiser 1993; Weiser & Brown 1996.) Challenge can also be phrased in terms of ambient display and access to information: the increasing computing power and complexity of distributed and networked smart components of a future home are counterbalanced by the design principle of “disappearing computer” – an environment where collections of artefacts link together and provide new behaviours and functionalities to users, while also supposedly easing the everyday life and demanding only peripheral awareness. (See the Disappearing Computer Initiative, *www.disappearing-computer.net* .) The requirements appear to be partly contradictory towards each other, at least in the current phase of development in technology, and related user cultures.

3.2. The Light and Sound Study

Light and sound were chosen as the focus areas into the second phase of the research on the basis of user responses in our probes, prototypes and scenario studies. The scenario method consisted of illustrated possible use situations of different proactive home designs and applications, and related interviews. One of scenarios was presenting a concept where smart home would be observing the sound levels in home, and informing occupants when the noise level rises high via means of changing the home lighting. By increasing inhabitants’ awareness of sound level, it also guided them to change their behaviour and lower the sound level (see below, Figure 4). In this study phase, a home technology system which takes actions that relate to the lighting and soundscape of home was perceived as more easily acceptable way of implementing proactive behaviours than a scenario where system would try to infer human intentions or to provide for example entertainment suitable for the given situation. Partially this can be related to the reluctance or unwillingness towards change in familiar and reassuring context, but partly to experience-based lack of confidence towards information technologies. It was hard for the informants to see how reliability could be improved by adding information technology to already reliable environment. The capacity of computing system was perceived as too limited to start making deductions about human mind and intention, particularly in complex and intimate social situations involving several people and their (sometimes conflicting) preferences. The assessment of our informants could be described as realistic, on the basis of previous experience.

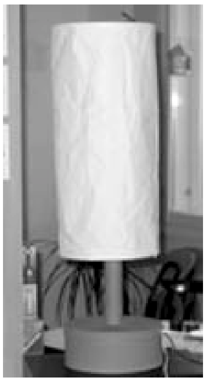
Figure 4: An illustrated scenario of a late social night, with the smart home providing sound level feedback via changing colours of a table lamp.

The research group decided to experiment with home lighting as a potential field for ambient interface design for smart homes. The first constructed prototype was a large standard lamp, originally coming from IKEA, a large international furnishing store chain (see Figure 5.). The lamp was constructed around two pairs of 36W fluorescent tubes, each pair chosen from the opposite ends of the colour temperature. The tubes were aligned in opposite corners, for emitting more even light when all tubes were lit. The fluorescent tubes were build to be dimmable and controllable on and off by the microcontroller inside the lamp. The fluorescent tubes were covered within the paper shade, which also covered most of the electronics, disregarding the lamp state interface, which was visible at the top of the lamp.


Figure 5: The large lamp prototype in use in the informant’s home.
On top of the lamp a light level sensor was installed, so that the lamp could adjust itself better to changing daylight levels. The lamp reads the light level from reflections and ambient light, not from the direct light level. It also kept a list of recent light levels in memory, so it could calculate a short term average. The lamp chassis contains 1W LEDs, that will light the lamp shade from the inside. RGB colouring was used, and the LEDs were distributed inside the shade for playful distribution of light. The design concept involved lights which were multicoloured for creating a live, party-like effect when loud sounds were being sensed. When in use, all LEDs were lit up simultaneously, the light intensity being directly proportional to the sensed sound level. The LEDs faded away within few seconds, if further loud sounds were not measured. There was a microphone connected to the microcontroller at the top of the lamp prototype sensing the surrounding ambient and direct sounds, which the microcontroller then used to light the LEDs.

The concrete research question at this point was focused on the interface between smart environment and its occupants. Our hypothesis was that a familiar design (the well-known IKEA style) would ease the adoption of new technologies, while new functionalities related to lighting being aware and reacting to the sound level would promote new behaviours. In actual use, the sound-reacting behaviour of the prototype proved so subtle, that it did not provoke strong reactions or new behaviours among our informants. We realised that in order to derive interesting answers to our research questions, the prototype needed to have more diversity both in terms of its design and behaviour.

After analysing the user experiences and lessons from the design of the first sound-level reactive lamp interface, a new collection of lamp prototypes was designed and implemented. These four lamp designs are introduced below (Figures 6-9). All lamps react to sound levels by changing intensity and colour. The lamps reacted to sounds by changing colours from blue to red trough green according to the volume, blue colour registering silence and the red light indicating the highest noise level. These systems were installed into two homes in Tampere, and one home in Helsinki. Each lamp stayed one week in each home. To collect experiences, and see how presuppositions changed with real contact with this kind of technology, people were interviewed before and after the study.



< *IKEA*: Hides technology by covering it with a stereotypical modern taste.

Granny: hides technology by covering it with a traditional “granny lamp” design. >

< *Glow:* hidden into a steel bar, LEDs illuminate a room by reflecting light from the roof.

Giger – a organic design: the aesthetics of this lamp is deliberately out-of-place in most homes. >

Figures 6, 7, 8, 9: Four different sound-reacting lamp design.

The first IKEA lamp shaped prototype had given the preliminary result that new, ‘smart’ functionalities could be hidden or made more easily adaptable into a regular home environment when embedded into familiar form. (Koskinen & Kuusela 2005.) This design research question was made easier to control and focus on, by applying these clearly distinct different lamp designs, while the basic behaviour of reacting to sound levels by chancing lighting, was kept the same.

The lamp has twelve 1W LEDs, with 4 leds for each colour. These were used to display the sensed ambient sound volume. The LEDs have special pattern, which they use to implicate increased ambient sound level. This pattern is shown in Figure Z. The LEDs have a certain lighting time, depending on the speed and length of the measured sound window. Each LED has its own trapezoid shaped area on the measured sound axis. As the Measured Sound Window (MSW) goes trough the measured sound level-axle, e.g. in a situation where someone has sneezed near the lamp, thus forcing the Measured Sound Window to roll on to the right, lighting on LEDs with higher numbers, and shutting down those just behind the MSW, and to give smooth transient effect from LED to another. The LED light output level is pulse width modulation controlled, with frequency over 200Hz in order to avoid blinking. The width of the MSW can be changed during operation. The basic setup of the colours of the LEDs went from blue to warm white, warm white to green and green to red.

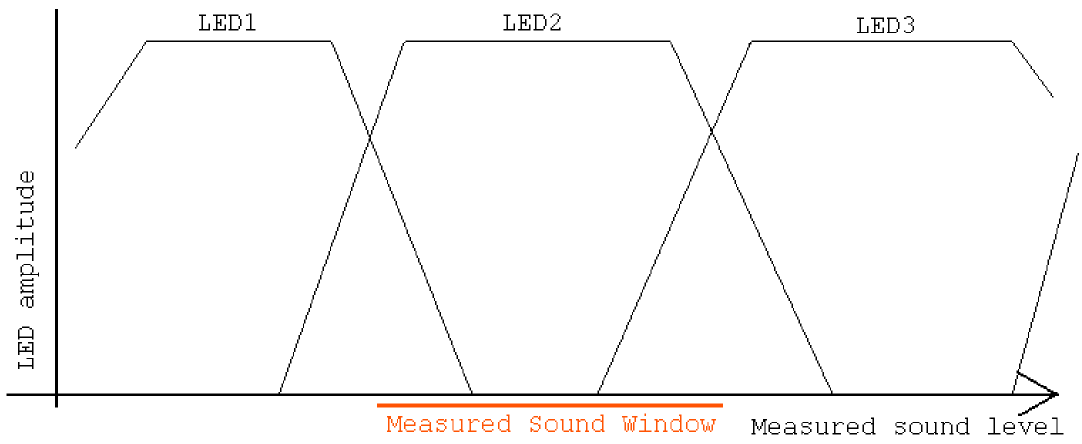


Figure 10: LED amplitudes depending on the sound level

The second generation lamp prototype had a microphone with amplitude based envelope filter, and direct signal sense circuitry. The envelope filter was used to determine the measured sound level. The maximum measured light level and the number of LEDs was adjusted so, that the last remaining light was lit when maximum sound amplitudes were measured. The lamps were set to have two different speeds settings for the MSW climbing towards the corresponding sensed sound level, and back from there. The fast setting was for quick and sharp sounds, and was in effect much more dynamic than the second, slower speed setting. The slow setting allowed for a small "sound memory", which showed the sound level for a few minutes instead of seconds as in the first one.

In the scenario study phase most of the participants assumed that sound-reacting lamp system's red colour indicating the loudest sound level could be obtrusive because it would require a lot of attention and sometimes informants claimed that it would be impossible to avoid loud voices or noises at home. However, during a four-week test period none of the homes perceived the red colour to be too obtrusive. Although prototypes differed in their design and intensity of light, the red light was not seen as taking too much attention. Some participants thought that if there are powerful voices at home, the lamp really should come to the centre of one's awareness and in that sense the red colour worked well. Their point was that when changing 'red', the lamps became "decibel meters" for a while, whereas otherwise they were perceived as decoration elements.

The lamp prototypes indicating a rough volume level were interesting in the sense that they made invisible information visible. The participants told how they were surprised during the first test days when the lamps reacted by changing red when they were, e.g. laughing or sneezing. Thus, their expectation had been that the prototype would indicate only steady sound level at home without reacting to sudden loud voices. However, as ‘lighting artefacts’ the prototypes formed a visible part of spatial order and technological ecology of the home but simultaneously they operated as experience prototypes, providing the participants with an idea how it feels when technology steers your attention to invisible sensorial issues.

The prototypes also blurred the distinction between lamps and technology. The role of domestic technology is often ambiguous, because domestic appliances and media technologies dominate the domestic space, but their role is not established in decoration magazines (e.g. Routarinne 2005). The position of lamps among domestic technologies is also interesting because they are perceived in decoration media more as decoration elements than domestic technology. In a similar way, some participants considered the lamp prototypes primarily as decoration elements while others perceived them more as decibel meters. An appearance and a placement of the prototypes were felt much more important in some homes whereas other homes focused mostly on the ways the prototypes react to different voices and noises. The interior decoration aspect was highlighted in the former whereas the technology aspect was more central in the latter. One results thus is that hiding the measurement elements and exact results is not a desirable feature, if this kind of ambient object is perceived primarily as a gauge by its users.

One family assessed already in the scenario interview phase that their home is so silent that there is no need for decibel information there, and their argument remained the same after the prototype experiment experiences. It seemed that in their case the visual scenario had provided them with a fairly realistic picture about the application because the stance did not change. They also argued that they have enough lamps in their small home so there was no need to a new lamp and this probably also decreased their interest. In the scenario phase a young couple assessed that they would like to use a “decibel lamp” system in their home and after the testing period this opinion also strengthened. Anyhow, it was proven that they would not take any smart lamp but only those fitting in their interior decoration. For instance, they argued that the version ‘Granny’ represents the ‘dated’ style they do not want to have in their home. Although they felt the technology of decibel lamp systems interesting as such, the design of the prototype made it inappropriate for their home. In another family a mother stated that she does not like the ‘romantic’ Granny because it reminds her too much from her childhood home’s antique furniture that children were not allowed to touch. Thus reasons for disliking certain domestic technologies are diverse and people’s mode of living, phases of life and socio-historical backgrounds play a central role in them.

3.3 Ambient Home Automation Study

In order to reach to real user information about proactive home systems, researching different ways of implementing smart home interfaces is not enough. We needed to set up a larger scale test environment, where real homes were augmented with sensors and programmable behaviours that would provide them with an overall experience of what it means to be living in a proactive home environment. At the same time, there were numerous technological, resource and even ethical constraints setting limits to how strong and active hold on people's lives our prototype system could have.

The key focus was on the acceptability of proactive technology in real homes, which was studied by providing our informants concrete and personal experience of functionality of a larger proactive system as set up within their own home. Primarily we wanted to provide our informants with an example of how different devices could autonomously interact with each other in their homes, thereby also highlighting "proactivity" as a feature of technology which acts on our behalf and anticipates our needs.

The starting point for implementation was that it had to be installable as straightforwardly as possible into real homes. The idea was to use existing lighting and other devices that are familiar elements to the users. We wanted to minimize the need to install new apparatuses to homes. Also, in this phase the design of devices or their role to acceptability was not in focus, but rather the new functionalities and how they are felt and accepted when combined with familiar home and its existing devices. One effect of this decision was, that it decreases the set of possible functions that could be used in the prototype. We chose only very basic tasks and functions for proactive augmentation, such as controlling the lights and waking up. The test periods with the system installed in a home ranged from a week to three weeks, and after the test, all the devices had to be removed without a trace. This also presented the team with a significant challenge in research design, since all permanent mounting methods had to be rejected, forcing us to use a set of temporary mounting methods (such as suction pads and adhesive pads). We also wanted to get an insight about how experience of domestic space potentially changes with new ambient elements.

To meet the requirements we chose a commercial home automation system known as X10 (*www.x10.com*), since it offers the possibility to use existing technology and to retrofit some compulsory new devices. The advantage in X10 is that it uses existing electrical power lines for communication between devices. However, the commercial software of X10 appeared to be rigid, and we replaced it with an open source software called Misterhouse (MH; *www.misterhouse.net*). MH combines the X10 hardware with a PC and offers a simple user interface as well as some basic means for programming and necessary object and method libraries. The logic of events and functions were programmed with Perl.

The basic functionalities of the system were lighting control, and routines assisting in waking up and going to sleep. These were performed by adjusting the lighting level of the house according to time of day and recorded motion sensor information. In addition to light, ambient sound was used both in morning and evening. The philosophy of choosing sleep as the part of life subjected for "proactive control" was related to sound and light already being technologies people appeared to be using for controlling their state of awareness and arousal, as the ubiquity of alarm clocks and clock radios proves. The "going to sleep" sequence was the more experimental part of our set-up; the concept was based on premise under which future home technology will adopt a more strongly proactive stance also towards the health of users. The relaxing, ambient sounds and dimming lights which activate when a preset "sleeping time" comes in the evening was designed to have a double function: firstly to signal the inhabitants that it is time now to go to bed, and secondly to have a relaxing and "sleep inducing" effect to the atmosphere of the home.

Figure 11: The control interface unit of X10 based home automation prototype system.

The objective of the wake up routine was to offer the user a calm and gentle way to awake, with slowly brightening lights and the sound of birds singing. The operation of the wake up routine starts 15 minutes prior to the wake up time (at "Preliminary State"). The desired time is set by the user before going to sleep. The routine increases lighting and sound volume steadily so that by the wake up time, they are at 50 % of their maximum level. The routine can be turned off any time by the user by pressing the switch-off button in the "alarm clock" interface. (See above, Figure 11.) In the case that the routine is not stopped within 10 minutes after the wake up time, the lighting and sound will slowly start to fade away ("Fading State"). The going to sleep routine works in similar manner as the wake up routine, however, the lighting power and sound volume are not increased but decreased. The exemplar of the floor plan of a test home with placement of devices is shown at Figure 12.

Table 1. The operation of the wake up routine in each state is explained. The purpose is to brighten the lights slowly and to offer a convenient environment to wake.

State	Function
WAKE UP ACTIVATED	The wake up time has to be programmed prior entering the state. The wake up routine is ready to be started as time condition is filled.
PRELIMINARY STATE	The wake up routine will start as the state is being entered. The bedroom lamp and the living room lamp are brightened linearly in 15 minutes up to 50 % of the maximum lighting power. Also ambient sound is played in the bedroom and in the living room. The sound volume level is very low at the beginning, but increases slowly up to 50 % of maximum.
RUNNING STATE	The coffee maker is switched on. The lighting power of the bedroom and the living room lamps, and the sound volume are further increased up to the maximum level.
FADING STATE	The lighting power of the bedroom and the living room lamps, and the sound volume level are decreased slowly.

SNOOZING STATE	Firstly, as the state is being entered, lights and sound will be faded. Secondly, the execution of the program jumps to the beginning of the wake up routine, and lighting and sound volume levels are increased. Snoozing state is on until the snoozing timer is expired.
WAKE UP DEACTIVATED	The bedroom and the living room lamps, the coffee maker, and all sounds are switched off.

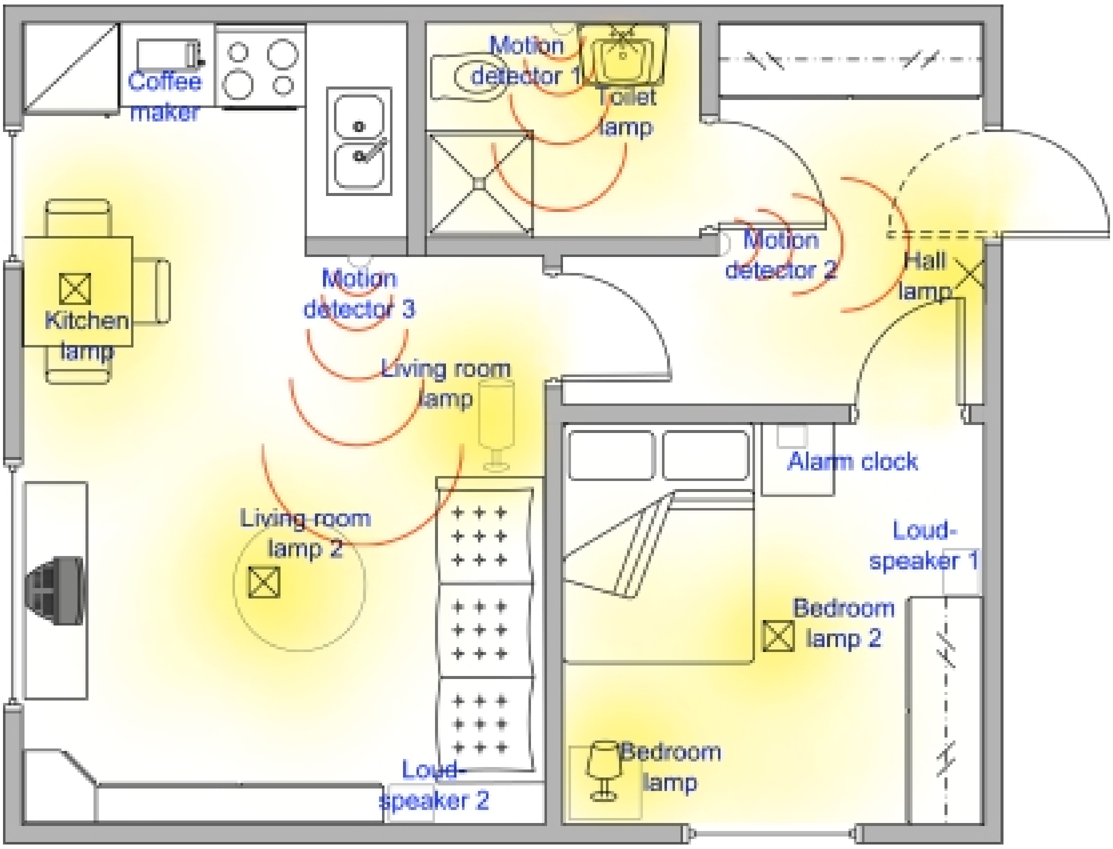


Figure 12. The imaginary floor plan showing the placement of devices attached to the proactive home system. The operational elements are named in the floor plan.

The lighting of home is adjusted according to motion sensor information. The time of day also affects in the toilet and in the hall: at daytime, the lamps are brightened to their maximum; at night-time, the lamps are brightened only to half of the maximum power. The purpose is to avoid the blinding effect as the user enters from a dark bedroom to a toilet or a hall with bright lights.

On the basis of our interviews, it is extremely important that the atmosphere at home is warm and homely. Finnish homes are often furnished with warm colours, soft textiles and wooden furniture. Especially when people expect guests or in the evenings, the lighting of the home is wished to have a warm shade. In that sense home environment differs a lot, for example, from an office environment. When we think of the visions of smart home as popularized in the media and advertisement, the atmosphere is often pictured to be rather cold and centred on hard technological element (cf. Jokinen & Leppänen 2005). The illustrations of smart homes are dominated by various electronic components enclosed in black or grey boxes, large displays and gleaming glass surfaces. We see here a contradiction between the visions of smart home interiors presented to public and appearance of today's homes. In our research, the approach was aimed to challenge this stereotypical image, and look whether bringing home new functionalities would not necessarily mean that, the atmosphere of the home has to change. New devices could equally well give the user the feeling that these are designed and intended to be used precisely in common everyday home environments, among real life. In our study, the interviewees were *not willing to compromise the feeling of cosy*. This should be taken into account when designing novel devices and smart services into homes.

In the beginning of 1990's Mark Weiser presented the idea of ubiquitous computing (see Weiser 1993). It is unlikely that our informants are familiar with the principle, yet, the attempt to embed technology is well known among general public. In our interviews, the wish to have embedded, unobtrusive devices was emphasized. This can be found also in the following quote:

> I definitely don't want here in evidence any more of those things that remind me about technology. Maybe then if they could be somehow hidden or so tiny that they would be out of my sight. (F, 33)

As pointed out in the interviews, our informants could accept technology more easily if it would follow concepts of ubiquitous computing and calm technology. As the idea of proactive computing goes even further compared to ubiquitous computing, by suggesting that people should be got out of the control loop in contrast to one-to-one interaction with technology, it should not be forgotten to make technology also embedded, ubiquitous and calm. In that sense, requirements of ubiquitous computing should be met prior to developing truly proactive technology. After testing the ambient home automation system the participants brought out that in the beginning of the test period they marvelled at what the system is all about and whether there is any logic in its functionality. Although the elements of the system were visible and mainly familiar to the participants they wanted to understand why it does what it does. This interest can be partly explained by a test situation and a tendency to domesticate new technology but they do not account for it entirely. We presume that rendering home automation systems more invisible and embedded in home environments sets a challenging question about how to design and present the 'disappearing' technologies as intelligible enough to their users.

During the home automation study it became clear that reaching the optimum adjustment of lighting in home environment is much harder a task than it appears to be at the first sight. Even though the system already contains different regulations or adjustments for bedroom, living room, and toilet, it is not even close to the optimum. The distinctly different nature of various home spaces and rooms sets varying requirements for lighting. In addition, the time of day, week, and year need to be considered. This raises the question whether the smart home should always also be truly adaptive, as suggested for example by Mozer et al. (1999). Central to the concept of an adaptive home is that it observes the lifestyle of the inhabitants and adapts its operation to accommodate to their needs. The participants also felt that the use of remote controls together with lamps is unnecessary because the distances in their home interiors are fairly short and because a common problem with all remotes is that they often go missing. Some participants suggested that they would like to have a room-specific adjusting point (e.g. a small touch screen) on the wall that would enable controlling all the lights of the room from one place.

It became also apparent that optimal placement of the motion sensors and lamps is difficult to know without trying them out in one's home environment. People are not necessarily so conscious of their or others' movement in the domestic space but use of motion sensor lamps especially in small apartments can make them annoyingly aware of others' moving and change of positions. Further, homes can involve areas (e.g. a balcony) that people want to be kept free of electric light and because of that they should opt in to be in darkness or natural light without a lamp switching on automatically when entering the space. The participant homes regarded as a most surprising or exceptional feature of the home system its ambient sounds and how they affected one's mood. They brought out that the sound growing louder slowly had a positive influence on the atmosphere during mornings and made the moment of waking up more smooth. However, one participant also noticed that the sound was almost too gentle for him, encouraging him to use the snooze function too many times. He felt that the waking up sound would be more efficient if it would include some sort of abrupt irritating effect in the end. Some felt it annoying that they had to install the time for going to bed in advance whereas others did not find any problem in it. In any case the sounds were considered as the elements that changed most the experience of one's home during the test period.

As a method, the prototype testing in people's homes succeeded well in elucidating the user experiences both in the case of the decibel lamps and the home automation system. Because the test period lasted always at least one week, the prototypes became more or less a part of daily life and in this sense the experiences and attitudes towards them were not so much dictated by the first impression any more. We noticed that introducing a "foreign" element into real home interiors would help to make more visible the often elusive and ill-articulated dimensions of home life and domestic settings. Moreover, when living with the prototypes, some informants changed their views on smart technologies, and concluded that intelligent home technologies in fact do not need to be something radically different as compared to contemporary homes. Even simple lamps equipped with motion sensors can provide new experiences that set into new light what will constitute "smart home".

In general, one should note that the user-centred study of proactive computing has its multiple challenges. Firstly, while setting up a larger-scale proactive system for home environment one faces substantial technological challenges, since there are no commercial solutions available to support complex or adaptive functionalities. Secondly, making these designs user-centred will easily involve users to the degree that may even appear contrary to the basic philosophy of proactive computing, which aims to "get humans out of the loop" (Tennenhouse 2000). There is no patent solution for these challenges at the moment, and we need more research which presents and tests out models of life for human agents and technological agents co-existing and co-operating in various combinations.

3.4 Approaches to Smart Home

The results presented next are yielded by analyzing together the scenario study's discussions about 'smart home' and the interviews conducted after the test of home automation prototype (see chapter 3.3). They represent repeated approaches that emerged when people discussed functionalities of smart home systems and assessed their acceptability and suitability to their own home. In the scenario study the product concepts of proactive computing were represented as sketchy drawings illustrating use situations or functions of technology. Thus, those visual scenarios did not deploy designated users or a linear narrative form. We presumed that this kind of open-ended and flexible implementation of the scenarios would enable people to better imagine uses of new applications in their own lives (Soronen & Kuusela 2005).

The participants highlighted that they want to keep control in their domestic space regardless of conveniences new proactive technology would make available. Sense of control was related to sufficient awareness of functionality of proactive systems. The border between obtrusiveness and sense of losing control seemed to be fine-drawn. The participants argued to value tranquillity in their homes. This did not mean that it should be quiet at home but that the domestic space is represented as an area where one is enabled to be at one's leisure always when feeling so (regardless of occasional conflicting interests on use of domestic space among household members). Tranquillity was also related to pleasing and well planned interior decoration. Although many participants liked the idea that domestic technology would be hidden under surfaces and inside furniture some of them emphasized that they would not want to be reminded all the while by the system that they are living in the home surrounded by the invisible technology. This concern was directed at the idea of the dweller who has to be all the time an active participator or decision-maker in the smart home environment (see also Jokinen & Leppänen 2005). On the other hand, human-like features, such as a speech user interface, were typically felt as making the home system too active and simultaneously decreasing the dweller's control over the living environment. As we expected, the participants were most wary of proactive technology that makes decisions on their behalf because a possibility of misinterpretations was felt then to be very high. Many participants emphasized that it is almost impossible that any computing technology would be able to presume their 'state of mind' or the activity they want do next (Soronen & Kuusela 2005). The participants claimed that in order to be acceptable the proactive system should be possible to switch off always when needed. They were also concerned about accessibility of user support and help desk services after these systems have been introduced in the consumer market large-scale. Thus, the smart home was perceived rather as a big computer than a place where one should live. Frustrations and problems encountered in a PC world evoked doubts towards the home working like a computer. In summary, this currently common view holds that *smart home is regarded as an unstable and obtrusive technology* that one can not trust in and control similarly like the home 'free' of smart technologies.

This view of smart homes could be related to the more implicit notion that the interior of smart home necessarily has a specific appearance. Few participants referred to the popular conception of smart home that is full of flashing lights, small screens and an interactive wall. A common notion of smart home as an environment that looks futuristic, ascetic, cold and too technical (see e.g. Leppänen 2001) leads easily to the presumption that one cannot organize and change domestic order in a free way because of embedded computing technology. The approach was based on the idea that *smart home can not look nice and cosy and the technology inside it constrains interior decoration*. In this sense the smart home technologies are perceived as opposite to cosiness which refers to particular look and feel of furnishings, colour schemes, textures and their physical comfort (cf. Garvey 2003). This approach was seldom mentioned explicitly although some participants highlighted that it is difficult to imagine invisible smart technology embedded in furniture and surfaces that look like the objects in their contemporary domestic environment.

> Somehow… home just is for the human, I think, and to me this means that there are perhaps some candle light and wooden materials, and softness and… than something different. But of course it can be that my notion [of technology] is a little bit stereotypical because allegedly the technology doesn't have to look as hard and glossy and steel-like. It can probably be something else also. (F, 33)

Thus, people presupposed that the functionality of smart technology embedded in domestic environment is in one way or another reflected in the appearance of home interior. Usually this meant that the smart home was conceived with exterior features that are familiar to people from current media technologies. From design perspective there appears be a substantial challenge in how to communicate to the users of smart home the fact that culturally familiar objects (sofas, pillows, tables, walls, floors etc.) have some new, technology-induced affordances and control functions (Kuusela & al. 2005).

Also a common attitude to smart home among the participants was the idea of smart home as something that would make life easier. Most of the participants claimed to be willing to live in homes that facilitate or automate some predefined chores or routines. For instance, waking up was seen as a routine that is repeated as fairly similar during the weekdays, and it was seen as a process that could be automated more. In the scenario interviews almost every participant hoped for a system that could increase light gradually, simultaneously playing pleasant music (thereby replacing the now common bleep of an alarm clock) and that would make coffee or tea ready for them in the morning. However, differences emerged when the informants started to assess whether the curtains should open automatically during or before the waking up or not. According to this view, the smart home technologies were regarded as making some dull routines more pleasant while also increasing the flexible availability of information and communication technologies around the house. An underlying idea was that *smart home technologies enable enjoyment and convenience that facilitate domestic life.* This approach also involved evaluation of smart home as something luxurious, and consequently unreachable fantasy that is nice to dream about but that simultaneously is impossible to obtain for most people.

One negative association that informants attached to smart home was the view that it could make people lazier. Part of the participants remarked that smart home technologies can lead to people's increasing helplessness by weakening their memory, thinking and other faculties that are related to actions while at home. They assumed that smart home technologies would involve many automated functions that would make decisions on behalf of occupants or remind them about things they should do next, and all this would change negatively how the home environment currently encourages human initiative, reflection and action. This line of thinking was based on an idea that when people become used to living surrounded by smart home technologies their functional modes and mental capacities will become reduced. In this approach smart home was read as *a technology that decreases people's independent initiative and restricts the contemporary ways of doing domestic things*. It was taken for granted that smart home would make people lazy both mentally and physically if the initiative of domestic activities is moved to the smart home system. It should be noted that the view can be linked to "technological determinism" as it suggests that technology has inevitably influence over humans, who just will adjust themselves to new features and behaviours suggested by smart technology.

All these abovementioned approaches to smart home have emerged in almost every interview. They should be read as conceptions that contemporary Finnish people interested in new technology used explicitly or implicitly as commonly recognizable associations with the smart home. Typically more than one of these conceptions was elicited during an interview. But it also should be noted that the participants often brought out both negative and positive sides of smart home, also inconsistently. Their views of smart home appear somewhat shapeless or underdeveloped, without enough concrete experiences to support them. Although all aforementioned conceptions were often identifiable in their conversation it did not mean that they always shared all the attitudes included in their discussion above. The participants also brought out particular situations and exceptions that could question the 'dominant perception' but this did not reduce their position as generally recognizable configurations of attitude.

If people adopt and purchase proactive domestic technology, it is evident that it will change their domestic life. But is equally likely that people will change and adapt the technology when they domesticate it into their homes and innovate new uses. If smart home is understood as a mixed use environment in which we still have some visible terminal devices but computing resources are distributed and hidden in microprocessors of domestic appliances and furniture, the idea seems to be fairly easily accepted among users. They are, after all, already living with various elements of home electronics, which tend to increase in homes. However, people also have pieces of furniture that they want to keep free from any embedded technology. For example, the participants mentioned rustic style furniture or antique as artefacts that one should not 'spoil' with embedded computing technology. Invisibility of electronics in itself does not make the home environment "calm" if issues of furnishing preferences, household compositions or social use contexts are not sufficiently taken into consideration. It also appears that contemporary popularity of home decoration and increased purchase of entertainment electronics in Finland does not directly support interest in smart home technologies.

4. The Main Findings: Facing the Challenges of Proactive Technology in Homes

During this research, already the methodology has provided crucial lessons: setting home as the context and maintaining a long-term contact with the informants creates a fruitful context for interdisciplinary research and innovation. On the other hand, the selected method requires substantial researcher resources, and a wide combination of competencies as it involves work at theoretical, methodological and implementation levels, bringing together the strengths of human sciences, art and design studies and technology research. The initial set of proactive technology design principles (see above, chapter 3.1) still appear valid conclusions, even if we want to emphasise that there are the common design principles for furniture and other home elements that need to be taken into account; proactive homes still continue to be and function in their traditional role of homes, first of all. However, there are some further results that are each related to certain challenges proactive technology must face when implemented in homes.

One of the general main findings of our research is that home is a sensitive environment where people often hold rather conservative attitudes towards "smart" technologies. This can be partly explained by the conception of smart home technologies in media and popular culture. The idea of smart home is associated with futuristic and ascetic home interior in which display walls and other very visible technical elements dominate the space. Because of that it is difficult for many people to imagine smart home technologies that are non-intrusive and to some extent invisible embedded in home interiors that can look like their contemporary homes.

On the other hand, people's notions on awareness of proactive technology's functionality are typically contradictory in the sense that people want to have a full control of domestic space but simultaneously they do not want to be aware of constant sensing and gauging actions of the system in the case when they already have accepted that functionality. In order to increase sense of control, the system should offer its users some sort of log files for checking what it has done and alternative set-ups and installations if users are not satisfied with existing ones.

It is also an important finding, that when access and interface to advanced and internally complex technologies is provided via familiar and comfortable, reassuring designs and implementations, then this clearly enhances their social acceptability and usability in a home context. It is also important to offer these domestic technologies with diverse designs because decoration preferences vary a lot in different homes. When embedded computing in furniture becomes more common both the design and usability will be key factors in acceptability.

One promising research direction that may lead into successful integration of smart technology into homes is that of "animistic" home elements, where cushions or other soft and familiar home objects are "brought to life" with technological means. As technological systems continue to develop in complexity and start displaying their own initiative and decision making potential, it is very important to enhance their social and psychological acceptability. There is a long tradition of dystopic technological fictions which display the ambivalence and distrust towards intelligent machines (Mäyrä 1999, 209). The simple interactions with a "smart cushion" or other familiar home element may offer a necessary counterbalance towards these initial fears or lack of trust.

It appeared in our research that the control of lighting and sound with movement or sound level sensors is mostly acceptable, when people retain a sense of control of the behaviour in their living environment, in our case via traditional back-up interfaces.

However, differences in interior spaces and household compositions should always be taken into account when devising functions that are activated by different sensors. For example, in small homes with more than one dweller, lights based on movement sensors can be felt obtrusive if they switch on and off too often. Therefore it is beneficial to think carefully where to place that kind of light functionality and if possible, to always test appropriateness of sensors and lamps' places before installing them permanently. Further, many families living in apartment buildings liked the idea of having visible information about sound level in the form of 'decibel lamps' while some families considered that sound level information is unnecessary for their home, and questioned the whole idea of integrating the decibel meter and table lamp. Hence this kind of auditory information made 'visible' appears desirable to some dwellers, whereas it is unwanted for others. Of course, there might be even more powerful proactive home technologies appearing in the future to address this area, such as proactive noise cancellation systems. Such developments, again, need their own user-centred studies before they are commercially introduced.

5. Conclusion: Researching for the Future

The role of smart technology is unlikely to stop its advancement in homes. Rather the opposite, the future generations of home-owners are increasingly savvy of computers and likely to welcome additional functionalities into their homes. However, our research uncovers substantial resistance towards smart homes. Turning to their homes as sites of relaxation and shelter from the world, the increasing complexity, need for endless updates, the potential for malfunction and thereby the increasing unreliability and user stress as notions our informants associated with information technologies, are factors they did not want to couple with their homes. Therefore, the technologically robust, fail-safe and non-intrusive character of smart home technologies is a key priority.

We have found that there are functionalities in homes that are more feasible for proactive implementation than others. Ambient elements, such as air conditioning, heating, security, and to a certain extent also lighting and ambient sound in homes are such features that inhabitants have a low threshold to assign for proactive technology control. However, when human intentions and interpretation of the sense and character of activity or event comes to question, even other humans such as family members have sometimes problems in deducing the correct line of action without making a direct inquiry. Therefore, it was not surprising that our informants were sceptical about the application of smart technology to take a strongly proactive, intention-anticipating role in their personal lives. But whether they would indeed be able to accept such applications if those actually were accurate enough in their predictive operations, remains for future research to solve. Using a team of professionals remotely operating a specifically rigged house would be a "Wizard of Oz" approach (as pioneered by Gould et al. 1982) into studying human-level intelligence as experienced in a proactive home prototype setting. But this kind of research would, of course, include its own considerable challenges.

The main derived lessons for research practise focus particularly on the necessity of interdisciplinary collaboration if changes and developments of technologies are investigated. A study that only utilizes interviews as its method, for example, and tries to deduce some conclusions about the acceptability of future technologies from informants who only have experienced current technologies, is inherently unreliable. The preconceptions and popular ideas will have a dominating effect on results of such a study. But if human sciences, designers and engineers are working together to realize some experiences of such future technologies for users, and they can have enough time to live with them, and domesticate the prototypes as parts of their life, then the results will have much more relevance for all parties involved. (For domestication of technology, see e.g. Silverstone & Hirsh 1992, Pantzar 1996.)

The subject of proactive technology itself proved to be a complex and also controversial issue to study. Methodologically it was challenging to reach for phenomena that actually is yet mostly beyond the capabilities of current state of the art information technology: an indisputably intelligent service that would be able to deduce human needs and intentions and thereby act on our behalf, in genuinely anticipating and taking action in proactive manner. Rather than attempting to implement such high-powered computational system, the research goal here was focused on the human interface and co-existence of humans and “living” technologies in the context of real homes and real people. Embedded processors, sensors and network capabilities were applied in everyday objects such as cushions, lamps and alarm clocks in order to learn more about the acceptability of various “smart” functionalities, the relation of design and technology in a home context, and about the applicability of our methodology. From a researcher angle, the results appear promising, and there surfaces apparent benefits that are to be gained by involving real users in the different stages of a research process, both as informants and co-designers, by inviting and eliciting their ideas from the potential applications of emerging technologies. The combination of cultural probes, scenario studies, minidesigns and experience prototype systems provided the interdisciplinary research team with a suitably wide set of tools to derive rich data to build the basis for knowledge and theory formation.

For a smart technology developer or designer, the lessons of research particularly focus on the proactive home technology design principles and their underlying case studies which we have created during our research. It would be most welcome to see examples of industry approaches where the users key priority for “feeling homely” that we have reported here would be taken seriously an implemented as the driving principle for smart home designs. Another important finding comes from a more action research oriented angle; as the informants were during their participation explained the options offered by contemporary technology, it in at least one case led to changes in their lives, as the family in question decided to purchase and install such home automation system for themselves. In more general terms, it appears that the increasing speed of development and complexity of home automation and electronics is such that there is an apparent need for a “home technology consultant” which would help people to make informed decisions on the basis of their needs, what technologies would be genuinely valuable in their case, and which would not probably suit them.

There is also the level of “techno-politics” that can be derived from this research, which concerns most directly the decision and policy makers. Contemporary citizens are in sharply unequal situations concerning the marketing and availability of home automation and proactive technologies. There is the possibility that without public discussion and proactive measures by means of recommendations or even regulations, there might be developments that are either unethical, or provide different groups in society unequal opportunities for taking advantage of technology's benefits. There has been active interest and encouragement from public research policies towards technical and commercial exploitation of opportunities opened up by ambient intelligence and advanced computer systems. Our research points out how important it is to listen actual users while developing new technology, and involve them while deciding on the directions and uses where these technologies are going to be utilized in future. The consequences, after all, are going to have an influence on everyone in the society.

6. Acknowledgements

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7. References

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