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PROBING A PROACTIVE HOME: CHALLENGES IN RESEARCHING AND DESIGNING EVERYDAY SMART ENVIRONMENTS

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Abstract: *Based on the results of a 3-year interdisciplinary study, this article presents an approach in which proactive information technology was introduced into homes, and discusses the derived design principles from a human-centered perspective. The application of proactive computing in homes will face particularly sensitive conditions, as familiar and reliable household elements remain strongly preferred. Since there is considerable resistance towards the increase of information technology in homes, both the calm system behaviors and the degree of variety in aesthetic designs will play major roles in the acceptance of proactive technology. If proactive technology will be an embedded part of a home's structures and furniture, it needs to blend with the normal, cozy standards of a real living environment and aim to enhance the homeyness or the key social and aesthetic qualities of homes.*

Keywords: *proactive computing, user-centered design, home technology*.

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INTRODUCTION: CHANGING ECOLOGIES IN HOMES

> *In a way, it could be a quite nice idea that there would be coffee ready and waiting when you wake up, or if the 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[1])

Modern homes are becoming increasingly laden with various technologies, ranging from new-generation kitchen utensils and domestic appliances to home computers, digital televisions, and wireless media servers. The sales of consumer electronics in industrialized countries like the USA appear to rise to record heights every year (Consumer Electronics Association [CEA], 2006.). One vision of the future repeatedly evoked by the electronics industry is the creation of the *smart home,* a new kind of technologically enhanced living environment. Yet, there are different versions of what "smartness" means in this context, depending upon whom you ask. Planning a home around a complex entertainment center may represent smart for some, whereas others emphasize home security systems, or even more ambitious home automation solutions, where numerous home elements, such a lighting, door locks, or window shades, are programmed to behave in certain ways.

Home automation is not near reality in most homes, not even in the highly technological West. Additionally, there is also some resistance towards the whole idea, as the quote above from one individual from our study illustrates. One can question whether there exists an actual need for which a smart home (as it is currently marketed) would be a solution. Perhaps, therefore, the issue should be approached from a different angle. It appears that we already are living in relationship with various devices and technologies, and our living is influenced by them even while we make decisions and apply these technologies in ways that shape their value and usefulness to us. These kinds of interdependent connections, and the networks they form, can be conceptualized as *ecologies*. While ecology is traditionally defined as a study of organisms and their environments, this concept has revealed its usefulness beyond the field of biology to encompass other entities and their environments, such as community ecologies, information ecologies, and media ecologies, among others. For example, Nardi and O'Day (1999, p. 49) define information ecology as "a system of people, practices, values, and technologies in a particular local environment." They emphasize that, when studying information ecologies, the spotlight is not so much on the technology as it is on human activities that are served by the technology.

One of the main conclusions from our research is that because the relationship between humans and their technology is complex, we need to develop a multidisciplinary approach to study our increasingly intensive and intimate relationship with technology. It is insufficient to regard the people who are adopting or rejecting new technologies as just passive consumers, since their attitudes and practices have a powerful effect on the success or failure of particular devices or services. It also would be a failure to overlook the important ways in which the design, distribution, and marketing of new technologies are affecting the relationship between the humans and the technology. As research and development practices become more closely informed by user studies, the clear-cut separation and opposition of the realm of production from that of consumption is no longer necessarily valid. For example, assuming that producer roles are distinctive from consumer roles might have been appropriate for an industrial society, but as much of modern production involves designing information systems and media content that is collaboratively produced, involving networks of people in various roles, the opposition between consumer and producer does not stay as clear. As participation and interaction are becoming the new standard of design, there is an increasing need for evolving further the practices for codesign and coproduction, where users and designers are conceiving and developing new concepts and products in a more collaborative and interactive manner.

The starting point of our research was the need to provide a human-centered view on the development of proactive technologies for homes. *Proactive technology* is related to a particular information-technology-industry-driven vision of the future, where omnipresent computing, sensors, 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 a processor-saturated view of the future. But when such views are raised to the agendas of researchers and developers, these visions also may carry some self-realizing power. It was our aim to confront the concept of proactive computing, adapt it to concrete local environments in real homes, and thereby produce a better understanding about the related acceptability, usability, and feasibility issues should such technologies indeed be adopted and installed in homes. In this way, our research is both a contribution to the critical studies of science and technology, as well as a call for more ethical and sustainable ways of developing new home technologies.

Actually, certain reasons exist for why we might have need for such technologies in the future. Some claim that the aging of population will necessitate the development of smart home environments (e.g., Baillie & Schatz, 2006; Dewsbury, Taylor, & Edge, 2001). However, as we argued in our book, *The Metamorphosis of Home* (Mäyrä & Koskinen, 2005), there are serious ethical considerations that must be taken into account if human contact, independence, and autonomy are becoming replaced by proactive technologies, as compared to assistive technologies, where humans themselves take actions with the help of technology. We claim that the perhaps most crucial need for proactive technologies in homes will be related to the information ecologies themselves and with their evolution. It is already becoming an observable reality and common problem that the omnipresent media and communication technologies also create stress and increase the complexity of life rather than just help us to cope (Edmunds & Morris, 2000). As information network connections become more prevalent in such ubiquitous devices such as televisions, stereo systems, and games consoles, as well as in mobile phones and cars, there also will be a related surge in e-mail, instant messaging, and other communications, much of it likely unsolicited (spam) or otherwise undesirable. As a result, the overall cognitive load on individuals must be taken into account in every context. Essentially, our information ecologies are rapidly becoming over-saturated or even polluted by nonessential information (Koski, 2001), and perhaps most needed will be proactive technologies to control and supervise all the other technologies that are fighting for our limited time and attention. Thus, one of our directives for proactive home technology design was that, if adopted, these technologies should enhance the homeyness of homes: to support and protect those qualities that are central for people in their homes, including peace, relaxation, intimate human relationships, and shelter from the pressures of modern life.

This article will seek preliminary answers to questions such as what design principles should be established for how proactive technologies are built and implemented in future homes and how can we develop a human-centered methodology for researching a technology that has not yet been fully implemented by industry or adopted into use. In our case, researchers with backgrounds in electronic engineering, sociology, the humanities, and industrial design collaborated in studying the multidimensional issues related to the changing user cultures and design challenges in the context of home technology development. Since our approach involved interventions within real homes (we introduced a prototype design of new home elements into existing home ecologies), our approach is in many ways similar to action research. In an early work, Robert N. Rapaport (1970, p. 499) 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" (italics in the original).

There are numerous practical issues related to the approach we adopted that will be discuss below. In a wider perspective, however, our research was designed to combine all three key knowledge interests identified by Habermas (1968/2004) in his *Knowledge and Human Interests*:

- technological (providing solutions for new and innovative uses of the potentials of emerging technologies)
- hermeneutical (aiming at mutual understanding)
- critical (aiming at the disclosure of errors in our systems).

In our research, this wide coverage of interests was only achievable with the help of broad-based interdisciplinary collaboration. As a result, while experimental designs and technologies were innovated, social and cultural studies into the significance of home were conducted.

Our research project was titled "Living in Metamorphosis: Control and Awareness in a Proactive Home Environment" ("Morphome" for short), and it was devised and carried out in close collaboration among three Finnish universities: the University of Tampere, the Technical University of Tampere, and the University of Art and Design in Helsinki. The project's original research question focused on investigating how distributed, nonintrusive technological 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 defining some key design principles for developing proactive technologies that we felt are appropriate for and acceptable in domestic environments by actual occupants, yet are also interesting in design research terms. The methodological challenge remained a constant concern as we approached the issue of engaging the human-centered research of future home technologies.

Some previous research offered models for the main alternative directions into studying smart homes (see Edwards & Grinter, 2001; Harper, 2003; Intille, 2002). The key issues relate to the role of control and how the human agency is being defined within the human–smart home relationship. Therefore, it's important to define whether, in this heart of the home automation,

1. the user is in control, in which most tasks are consciously triggered;
2. the home (technology) is in control, in which most tasks are automatic;
3. learning models are applied, in which either the user is adapting to the principles of the environment or the environment learns from and adapts to the user.

It should be noted that all of these relationships are reciprocal, and highlight the symbiotic relationship humans have with their environments. Yet, we were not only following the line of study of "situated actions" (Suchman, 1987), but also were looking into technologically codetermined actions and relationships within situations in which the technology itself starts to exhibit adaptive, reactive, and proactive ("intelligent") traits.

We will first discuss our methodology, and how it was implemented in the various phases of research. Then we present our derived results. Finally, we discuss the lessons learned from the entire 3-year research process.

THE INTERDISCIPLINARY METHODOLOGY

We have mentioned briefly the overall interdisciplinary character of our research, and how it intersects and combines the human sciences (hypermedia research), design research (industrial design), and personal electronics (research into information technology). Since the phenomenon of powerful and intelligent computing technologies cohabiting homes with human occupants is still mostly futuristic, our approach could not focus solely on a methodology that describes and analyzes existing user behavior. Still, 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. As a result, our research required implementation of some kind of prototype systems, at least up to the point where an experience of "intelligent-like" features would be achieved. In the design research field, this approach is called *experience prototyping*, which means researching the user's reactions to representations that are devised to convey a sense of what it might be like to engage with future, not-yet-existing technologies, services or environments (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 also was divisible into different phases or dimensions in terms of its application and implementation. Thus, the descriptive phase of a user study aimed to gather information that would help us define how our informants understand "home" in the first place, and what their relationship is to technology within the home. From an applied angle, the results of the user study then were used as background research to guide the design principles for use scenarios or prototypes that were created and tested in the subsequent phases of the research. We used both *scenario studies*, where possible use situations of proactive home technologies were illustrated for and discussed with our informants, and *prototype studies*, which required construction of functional implementations. The prototype studies consisted of research into technologies and design approaches suitable for researching proactive technologies in homes. We concluded the research process with another user study in which the user informants interacted within a home environment modified by our prototype design. The hermeneutic circle was closed with the analysis of the results from the prototype study that provided inspiration and data for new designs, prototypes, and user studies.

The data gathered in the user studies have been analyzed in a qualitative way. The aim has been to understand the diverse elements affecting people's attitudes toward proactive computing in home environments. It should be noted that the number of informants in prototype studies has varied in the different phases of research; there were 27 households in total participating in the research, but the number of households per single phase of study varied from 2 to 12. In terms of size, the participating households also had a great range, from a single person household, to families, to a commune of five adults living together, but not all persons in a household necessarily participated actively in the study. All informants were Finnish people, varying in age from preschool children to working people around 60 years old. Almost all of these different compositions of households were living in a specific 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 toward new domestic technologies. Rather they should be construed as the researchers’ interpretations about the participants’ adopted and, to some extent, unquestioned stances towards their homes as technological environments 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. formulating a pre-understanding of the issues, challenges, and concerns on the basis of earlier research and then defining the research questions
2. conducting the domestic probes study
3. formulating of the first design principles
4. implementing the first design experiment: the pillow study
5. revising the principles as drivers for design and technology implementation
6. implementing the design principles as scenarios of future homes and evaluating them within interviews with the study participants
7. implementing new technology and experience prototypes in two sequential studies, with the focus on light and sound
8. analyzing, drawing conclusions, and finalizing a revised set of design principles.

Each design phase also included its own internal phases of hypothesis setting, prototype design, implementation, testing, and revision of the 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 to people not working with new computing technology; concretizing them was a challenging task. The scenarios and experience prototypes have served our project as tools, giving participants an illustrating or concrete idea about potential applications for the home environment in near future. These phases were also used as a means to get people accustomed to the ideas and potentials of novel technologies. Although the attitudes emerging from the scenario studies and prototype testing are not equal to living with proactive technology constantly, they do make people more aware of their existing domestic environments and the technologies already included. For instance, the existing devices, furniture, and other objects were considered in a new light when product concepts were brought into the home by means of scenarios and prototypes.

The participants remarked themselves that it is difficult to imagine living in a home surrounded by proactive technology. Most likely, this difficulty relates to the nature of the home as a place in which many habits are often carried out in a distracted or routine manner. Thus it can be challenging for people to assess the consequences of new technologies for domestic practices or way of living because these dwellers are not necessarily aware of their everyday activities and the role of technology in them. However, scenario and prototypes studies can make domestic routines and the embedded or underlying values more visible when people must consider why they are willing to try one technology while unwilling to try another. Therefore, providing an illustrating idea or allowing personal experience of new technology not only works as an inspiration for discussions but also can enable people to become more aware of their domestic habits and chores.

Because the home is such a familiar and taken-for-granted environment, it can be beneficial to give people tools to enable them to see their own homes through new eyes. The prototypes can be used as a means to introduce something ambiguous or strange into the familiar everyday environment. Gaver, Dunne, & Pacenti (1999) consider *ambiguity* 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 artifacts 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 they also spur people to imagine how they might personally use and appropriate these artifacts and what their everyday lives would be like as a consequence. Bell, Blythe, & Sengers (2005) call a fairly similar approach *defamiliarization*. Defamiliarization was originally introduced as a literary technique utilized in design processes as a tool to call 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 simultaneously constrain the design space. Thus, examining these assumptions can open new and more reflective directions in which to design (Bell et al., 2005). As applied in our studies, the aims of defamiliarization and ambiguity were to facilitate people's reflection on their perceptions that seem natural and self-evident within the context of domestic technologies.

People's discussions about their experiences in a modified home environment provides designers and researchers with the opportunity to consider the existing cultures of the home life and to develop new alternatives for domestic technology design. In our study, for example, the participants felt sometimes strange while testing the prototypes, such as the decibel lamps, because by changing the ecology of home in this way we made some aspects of domestic life more visible than before. The visualization of auditory information was a new experience that made the participants more aware of the soundscape of their homes, and its silent and loud moments. In the same vein, the gradually rising sounds of the singing bird used in the waking sequence of our final study made our informants conscious of what effect the typical sounds of alarm clocks had on their feelings during the waking process. It also got them to ideate alternative ways for waking in the morning or retiring in the evening.

Meanwhile, the adapted home lighting automation system increased the participants' awareness of movement in their homes. Especially in the beginning of the test period, the participants felt some of the features intrusive, such as the audible snaps coming from motion sensor switches. Lights reacting to movements made the dwellers prominently aware of others walking in the space or changing position while sitting on the sofa near to the test lamp. Just as the decibel lamps helped make the soundscape of the living environment more visible, so the lighting sensors drew attention to the usually unnoticed movements within the space.

STUDIES INTO HOME TECHNOLOGIES

The Domestic Probes Study

The starting point for the first research phase was the realization of how complex the social and material environments of homes really are. Each person perceives multiple private and public dimensions of significance in the home, with an increasingly complex network of meaningful relations overlaying that when several people inhabit and share the same space. As we were interested both in producing qualitative understanding about peoples' relationships to their homes and home technologies, as well as to produce qualitatively driven data that would also be suitable for inspiring our design research for concept exploration, we applied a design research approach called *cultural probes.* Originally created by Tony Dunne and Bill Gaver at the Royal College of Art (see Gaver et al., 1999), the cultural probes method facilitates user creativity through the philosophy and practice of codesign, rather than treating informants simply as sources for knowledge that only the researcher is able to derive. We devised a group of self-documentation tasks, materials, and the accompanying instructions adapted from the cultural probes method to provide our informants with a rich set of tools to explore meanings, values, and emotions that they relate to their home and the technologies it contains (see Figure 1). The probe packages were given to the participants when they were first contacted, at which time the contents of package were briefly introduced to them. After the participants had worked on their assignments using the provided camera

Figure 1. The domestic probes package included personal and shared workbooks, disposable cameras, drawing pens, glue, and animal stickers. Participants used these items to complete assignments to probe and concretize their personal and communal perspectives of their home environments and the various technologies contained there.

and other probe materials, their creations were analyzed and then reflected upon in design workshops by the researchers from multiple disciplines. Later, group interviews were conducted, where the research team's interpretations were discussed with the informants.

The main outcome of this process was a better understanding of how sensitive the quality of homeyness of a home is. One's sense of home is produced by daily actions, memories, and affective relationships that are related at the material level to familiar objects and to their placement in the spatial order of the home interior (see Soronen & Sotamaa, 2005, pp. 56-60). Some of the probes assignments involved informants drawing various "psycho-geographic maps," where they illustrated both their human relationships and relationships with home technologies. For example, one task required them to draw a floor plan of their home and then to attach animal figures to it to mark the locations and affective character of technological devices they owned (see Figure 2). The probes inquiry as a whole was a particularly helpful method in revealing the hidden emotional and social network of significances that invisibly surround home technologies. Different devices carried with them associations with stressful or pleasurable situations, or emotional traces derived from their links with various family members or friends.

Another finding was that the relationships between people and their technologies were ambiguous: Created not only by choice and taste but also by necessity, household compositions and the compromises among household members often dictated the presence and location of some devices. It also became clear that it is misleading to speak about the domestic technology in the singular because there are different hierarchies and roles among

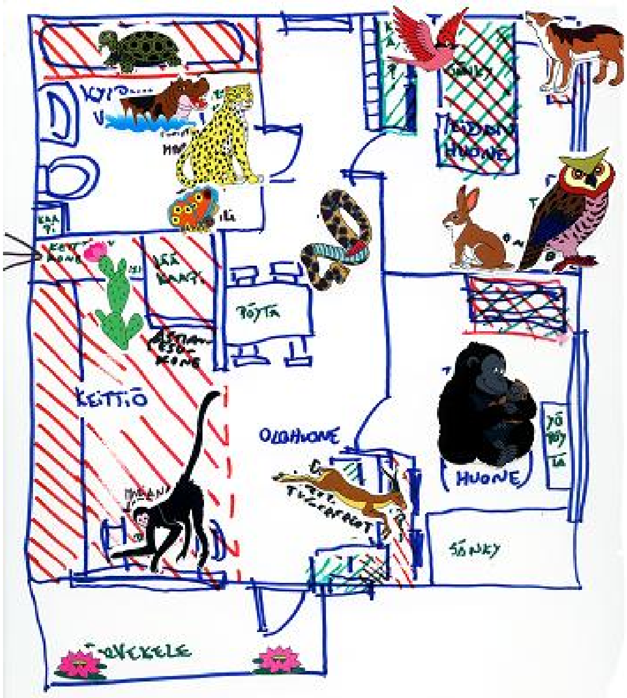

Figure 2. A floor plan drawn by an informant, where the animal stickers represent different devices. The use of the animal figures proved to be an unconventional yet inspiring way to describe and discuss the affective character of domestic technologies.

domestic technologies. Media technologies were perceived as authentic technologies while kitchen and bathroom appliances were regarded more as fittings of those rooms than as technology per se. This can be explained by the various presumptions and experiences that people associate with these technologies. Domestic appliances are often perceived as simple devices that one can use without effort or the study of manuals, even though many of them involve complex electronic and digital controls. People also expect that these stand-alone appliances do not crash easily (as do computing systems), and this reliability has enabled people to forget that these technologies are complex entities (Edwards & Grinter, 2001). Perhaps the most important thing, however, is that media technologies are perceived as status devices that tell about the technological standard of one’s home. This relates also to the stereotypical notions about “white goods” (referring to most appliances) as feminine and “brown goods” (referring to most electronics) as masculine. As time-saving technologies related to domestic work and hygiene, white goods are typically associated with cleanliness, simplicity, transparency, and utility. Alternately, brown goods are for leisure and entertainment, and they seem to signify complexity, cleverness, opacity, and rich content (Cockburn & Ormrod, 1993, pp. 100-104).

Because of its elusiveness, a person’s experience of the domestic atmosphere is challenging to study empirically (Pennartz, 1999). In our interviews, people frequently had no words for describing relevant elements of their domestic atmosphere, but the tasks of the probes package made the process easier to approach. By means of the probes kit, people could concretize and illustrate which aspects produced homeyness in their homes. Tasks also encouraged people to consider both the personal and familial significance of domestic technologies and their uses. Thus, the tasks illuminated shared and personal meanings within the domestic environment. Further, the probes made people question some taken-for-granted aspects of domestic life or technologies. In this respect, the probes together with the interviews opened up new ways for researchers not only to perceive the domestic technologies in the informants’ existing contexts but also to ideate promising directions that proactive technology could take in order to support a cozy ambience and sociality within the home.

The Pillow Study

While the probes study was underway and the researchers’ understanding of the homes was getting deeper and more multidimensional, the first prototype study phase was started. After establishing that technology use to enhance the sense of homeyness would be a key design goal, our team decided to experiment by introducing smart technology in the shape of a pillow. This was based on our analysis of pillows and cushions as intimate and personal elements, ubiquitous in homes, and, in their softness, also as things that appear to be situated at the opposite end of the mental spectrum of stereotypical conceptions of the high-tech home of the future (Mäyrä & Koskinen, 2005) that we were interested in challenging. Rather than stressful and hard, pillows are associated with comfort, relaxation, and softness. On the other hand, many traditional smart home concepts rely on the 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 a direction that would explore ambient and tangible interfaces. Cushions and pillows were perfect objects from this perspective.

A simple technical prototype was implemented, which operated as an embedded context-aware interface. It consisted of a pillow 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 a RFID (Radio Frequency Identification) connection that was used to provide the pillow with a crude means for sensing its surroundings. As soon as a RFID tag was within range of the reader, the embedded electronics emitted a prerecorded sound. The pillow was covered by fake animal fur, and the sounds it produced imitated animal sounds. This was related to the hypothesis that the limited sophistication level of the test system would be suited better by a perception of animal intelligence rather than by human intelligence, which the use of human voices for interaction would have suggested. The test users were provided with several things. First, they were given several beanbags with embedded RFID tags, each of which elicited a different sound associated with it from the reader when it was brought within range. A pillow with the embedded reader was also provided. The participants also received a loose set of instructions detailing various ways of interacting with the beanbags and pillow. And, finally, they were provided a video camera to record the run of events (see Figure 3). The pillow was field-tested with three families with children.

There were some technical issues in the testing that limited the sensitivity and range of RFID reader, and it was not possible to combine the different sounds as freely as was originally intended. Nevertheless, some basic interaction between the subjects and the prototype was possible. The main finding from the testing in real homes was that integrating interactions with smart home technologies can indeed be perceived with positive affect if they are embedded in familiar and soft home elements such as cushions or pillows.

The informants appeared quite creative in their uses and ideas for further development of such technologies. When interviewed, the child informants suggested uses where a smart pillow could become the “emotional companion” for the occupants of their home. Such an interface for a smart home could comfort its user and provide companionship and access to

Figure 3. A child informant uses a beanbag to experiment with the sounds that the pillow prototype makes.

house services as the occupant relaxes, hugs, or rests on the pillow while watching television or reading. In this concept, touch and sound, and the mere proximity of the pillow, provided rather natural and nonintrusive modalities for control in the shape of a pillow. The adult informants suggested that a proactive system, in general, should provide services as a secretary or manager, assisting the family members in the challenges of organizing their daily lives. For example, a future version of the pillow companion could make sounds to remind or motivate children to do their homework before their favorite television show starts, or even somehow communicate more complex messages, like alerting them when books are due to be returned to the library. Such typically messy everyday information management systems that consists 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.

The First Iteration of Design Principles

After the probes and pillow studies, we had enough experience and information to formulate an initial set of proactive home technology design principles. These served as a basis for further research, as we pursued to implement them in scenario and prototype studies, and to collect feedback about them from our informants. The principles are presented in Table 1.

Following the creation of these principles, we determined two basic directions our research could have taken: focus on the interactions and cohabitation in a home augmented with

Table 1. The Design Principles for Proactive Home Technology (Mäyrä & Koskinen, 2005).

Main Principles	1. *The principle of consistency*. If a function or element is delegated to be controlled by a proactive system, that function or element should demonstrate similar behaviors consistently.
	2. *The principle of personalization*. Smart home technology should follow the “rules of the house,” reflecting practices and preferences adopted and followed by this particular individual or family within their private space.
Additional Principles	3. *The principle of embedded media interface*. The main goal and task for proactive technologies in homes are providing filtering and control in negotiating the charged boundary between the home-as-shelter and the need 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*. Proactive services are joined with physical objects to afford multimodal, sensory-rich interactions, as well as to provide usable and aesthetically pleasing interactions for future homes.

strongly proactive technology, or follow the "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 a case as the "weak" alternative, which is a bit closer to the situation of interactive computing. Here, the state and operations of smart technology need to be conveyed to the human occupant: The system will notify the user and offer alternatives, but the choice of accepting or cancelling actions remains with the occupant, rather than completely removing the user "from the loop." Weak proactivity is not as efficient as its alternative if the primary consideration is reducing the users' cognitive load. However, based on our interviews and other user studies, the human-supervised direction of smart home technologies was considered more acceptable and ethically sound than the totally unseen and autonomous operation of technologies in homes.

The design of weakly proactive home technologies is related to the research into "calm technology," as approached from within the field of ubiquitous computing (see Weiser, 1993; Weiser & Brown, 1996). The challenge can also be phrased in terms of an ambient display of 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 the "disappearing computer," an environment where collections of artifacts link together and provide new behaviors and functionalities to users while also supposedly easing the everyday life and demanding only peripheral awareness (see The Disappearing Computer, 2002-2003). The requirements, however, appear to be partly contradictory towards each other, at least in the current phase of development in technology and related user cultures.

A Scenario Study of Light and Sound

Light and sound were chosen as the focus areas for the second phase of our research, based on the users' responses in our earlier probes, prototype, and scenario studies. In the scenario method, possible proactive home designs and applications were discussed with the help of illustrations that described various use situations in the future. Twelve households participated in the scenario study phase. One of scenarios presented a concept where the smart home would monitor the sound levels in the home and inform occupants, via changes in the home lighting, when the noise rises to a certain level. By increasing the inhabitants' awareness of sound levels, the process also would guide them to change their behavior and lower the sound level (see Figure 4).

In this phase, a home technology system that takes actions related to the lighting and soundscape of home was perceived as a more easily acceptable way of implementing proactive behaviors than a scenario in which a system would try to infer human intentions or to provide, for example, entertainment suitable for the given situation. To some degree, this can be related to the reluctance or aversion of the subjects towards change in familiar and reassuring contexts. But equally important was the subjects' general lack of confidence capacity in a computing system perceived as too limited to start making deductions about the human mind and intentions, particularly in complex and intimate social situations involving several people and their (sometimes conflicting) preferences. The assessment of our informants, based on previous experience, could be described as realistic.

Figure 4. An illustrated scene from a late night social, with the smart home providing sound level feedback via changing colors of a table lamp.

The Light and Sound Prototype Studies

Based on the results from the scenario study, the research group decided to experiment with home lighting as a potential field for an ambient interface design for smart homes. The first constructed prototype was a large standard lamp[2] (see Figure 5). The lamp was reconstructed around two pairs of 36W fluorescent tubes, each pair chosen from opposite color temperatures. The tubes were aligned in opposite internal corners to emit an even light when all tubes were lit. The fluorescent tubes were built with a dimming capacity and the on/off switch was operated by the microcontroller inside the lamp. In addition, multicolored light-emitting

Figure 5. The large lamp prototype in use in an informant's home.

diodes (LEDs) were installed in the interior. The fluorescent tubes and most of the electronics other than some control electronics visible at the top of the lamp were covered by the paper shade. This study involved testing in two households.

A light level sensor was installed on top of the lamp so the light output could be adjusted better to the changing light levels in the environment. When in use, the LEDs would light up simultaneously and in intensity directly proportional to the sensed sound level. The LEDs faded away within few seconds if further loud sounds were not measured. The microphone connected to the microcontroller at the top of the lamp prototype sensed 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 the smart environment and its occupants. Our hypothesis was that a familiar design (the well-known lamp style) would ease the adoption of new technologies, while new functionalities related to light reacting to the sound level would promote new behaviors. In actual use, however, the sound-reacting behavior of the prototype proved so subtle that it did not provoke strong reactions or new behaviors among our informants. We realized 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 behavior. Still, this first-round lamp-shaped prototype had demonstrated that smart functionalities could be hidden in, or made more easily adaptable into, a regular home environment when embedded in familiar forms (Kuusela, Koskinen, Mäyrä, & Soronen, 2005).

After analyzing the users' experiences and lessons from the design of the first sound-level reactive lamp experiment, a new collection of lamp prototypes was designed and implemented. The design-related research questions were made easier to control and focus on by applying clearly distinct lamp designs while the basic behavior of sound levels causing lighting changes was kept the same. The four lamp designs (Figure 6) reacted to sound levels by changing the intensity and color of the light. These systems were installed in two homes in Tampere and one home in Helsinki. Each lamp stayed one week in each home, one lamp at a time. To collect informants' experiences and see how presuppositions changed with real contact with this kind of technology, the people were interviewed before and after the study.

In the earlier scenario study phase, most of the participants assumed that a sound-reacting lamp system's red color indicating the loudest sound level could be obtrusive because it would draw a lot of attention, and informants claimed that sometimes it would be impossible to avoid loud voices or noises at home. However, during the 4-week lamp-testing period, none of the informants perceived the red color as too obtrusive, even though the four prototypes differed in their design and intensity of light. In fact, some participants thought that if there are powerful voices at home, the lamp should come to the center of one's awareness and, in that sense, the red color worked well. Their point was that lamps remained in their usual role until, by becoming red, they effectively functioned as decibel meters for a while.

The lamp prototypes indicating an approximate volume level were interesting in the sense that they made invisible information visible. The participants told how surprised they were during the first test days when the lamps turned red when they were laughing or sneezing. Their expectation had been that the prototype would indicate only steady sound levels in the home, and its reaction to sudden loud voices was a surprise. However, as lighting artifacts, the prototypes became visible parts of the spatial order and technological ecology of the home and simultaneously operated as experience prototypes, providing the participants with an idea how it feels when technology steers your attention to invisible sensorial issues. The role of domestic technology is often ambiguous because domestic appliances and media technologies dominate the domestic space. Yet their roles as aesthetic elements are not typically established in decoration magazines (Routarinne, 2005). Our lamp prototypes blurred the distinction between decoration and technology items: They were interpreted as both. Some participants considered the lamp prototypes primarily decorative elements while others perceived them more as decibel meters. The appearance and placement of the prototypes were felt much more important in one home whereas informants from another home focused mostly on the ways the prototypes reacted to different voices and noises. A playful attitude to interior decoration was prominent in the first case, whereas more conventional attitudes towards metering devices were central among the informants from the latter home. In any case, if the visual design of the lamp was felt pleasing, it also increased to some extent the participants’ interest in the decibel measuring action.

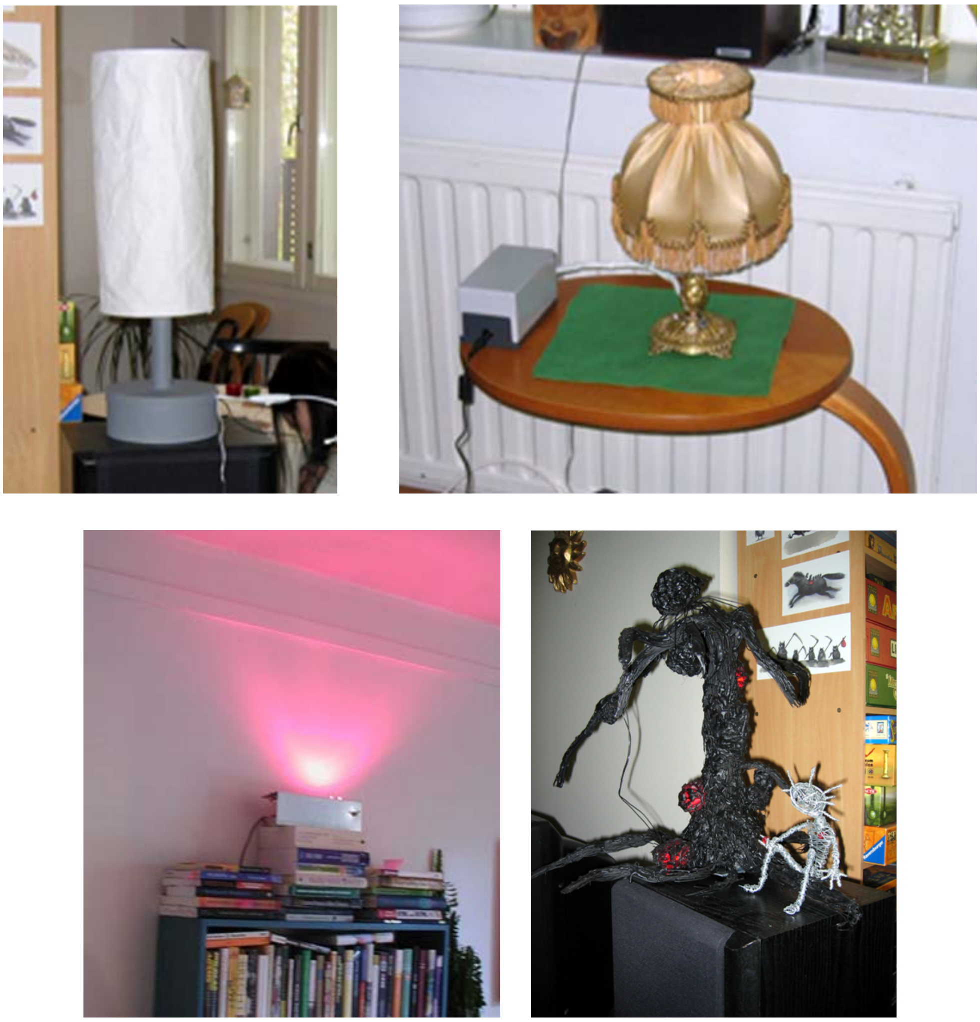

Figure 6. The four different sound-reacting lamp designs. Clockwise, from top left: “IKEA,” “Granny,” “Giger,” and “Glow.”

A young couple determined, already in the scenario phase, that they would like to use a decibel lamp system in their home and, after the testing period, this opinion strengthened. However, their results demonstrated that they would not take just any smart lamp, but only those fitting in their interior decor. For instance, they argued that the Granny version represents a dated style they do not want in their home. Although they felt the technology interesting, the visual design of this prototype made it inappropriate for their home. Reasons for disliking certain domestic technologies were diverse and people's mode of living, phases of life, and socio-historical backgrounds played a central role in their reasoning. Although there were some differences in preferences of style among household members, they all shared an opinion about the prototype they wanted least.

Ambient Home Automation Study

In trying to obtain actual user information about proactive home systems, we found that 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 behaviors that would provide residents with an overall experience of what it means to be living in a proactive home environment. At the same time, numerous technological, resource, and even ethical constraints set limits on how strong and active a 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 experiences of the functionality of a larger proactive system within their homes. Primarily we wanted to provide our informants with an example of how different devices could autonomously interact with each other in their homes, thereby highlighting proactivity as a feature of technology that acts on our behalf and anticipates our needs. We also wanted insight into how the experience of domestic space potentially changes with new ambient elements.

The starting point for implementation of this research phase was that it had to be able to be installed as straightforwardly as possible into real homes. We wanted to minimize the need to install new apparatuses in homes, so the idea was to use existing lighting and other devices that are familiar elements to the users. Also, the design of devices or their acceptability was not the focus of this phase; rather we emphasized the new functionalities and how they are perceived and accepted when combined with the familiar existing devices within the home. One effect of this decision was that it decreased 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 lighting control and the waking and retiring routines. Furthermore, all the devices had to be removed without a trace after the test, which presented the team with a further challenge in research design. Since all permanent mounting methods had to be rejected, we were forced to use a set of temporary mounting methods (such as suction cups and adhesive pads). The control interface (Figure 7) was designed to resemble a clock radio and thereby to fit easily in a bedroom. This study involved two households.

We chose a commercial home automation system known as X10[3] to meet our requirements since it offers the possibility for using existing technology and for retrofitting some compulsory new devices. One advantage in the X10 is that it uses existing electrical power lines for communication between devices. However, the commercial software of X10

Figure 7. The control interface unit developed for the X10-based home automation prototype system. The unit was a black box, approximately the shape and size of a common clock radio, with several buttons and a LCD screen available for users to make changes to the morning and evening time presets of the home automation system.

appeared to be too rigid, so we replaced it with an open-source software called Misterhouse.[4] By combining the X10 hardware with a PC, Misterhouse offered a simple user interface, as well as some basic means for programming and necessary object and method libraries (the key elements needed for object-oriented programming). The logic of events and functions were programmed with Perl.[5]

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 levels of the home according to the time of day and motion sensor information. (See Figure 8 for an illustration of the setup.) In addition to light, ambient sound was used both in the morning and evening: the sound of birds singing in the morning, and the sound of the sea in the evening. Our philosophy for choosing sleep as the part of life subjected to proactive control was related to the fact that people already use sound and light as part of technologies for controlling their state of awareness and arousal, as the ubiquity of alarm clocks proves. The going-to-sleep sequence was the more experimental part of our setup, based on the premise that future home technology will adopt a more strongly proactive stance towards the health of users as well. The relaxing, ambient sounds and dimming lights that became activated when a preset "sleeping time" arrived were designed to have a double function: First, to signal the inhabitants that it is time now to go to bed and, second, to create a relaxing and sleep inducing effect in the atmosphere of the home.

The lighting of the home was adjusted according to motion sensor information. The time of day also affected the lights in the bathroom and hallway: In the daytime, the lamps operated at their maximum, but at night, the lamps could be brightened to only half of the maximum power. The purpose was to avoid the blinding effect that occurs when the user enters these areas from a dark bedroom.

On the basis of our earlier interviews, subjects emphasized the extreme importance that the atmosphere of a home be warm and homey. Finnish homes are often furnished with warm

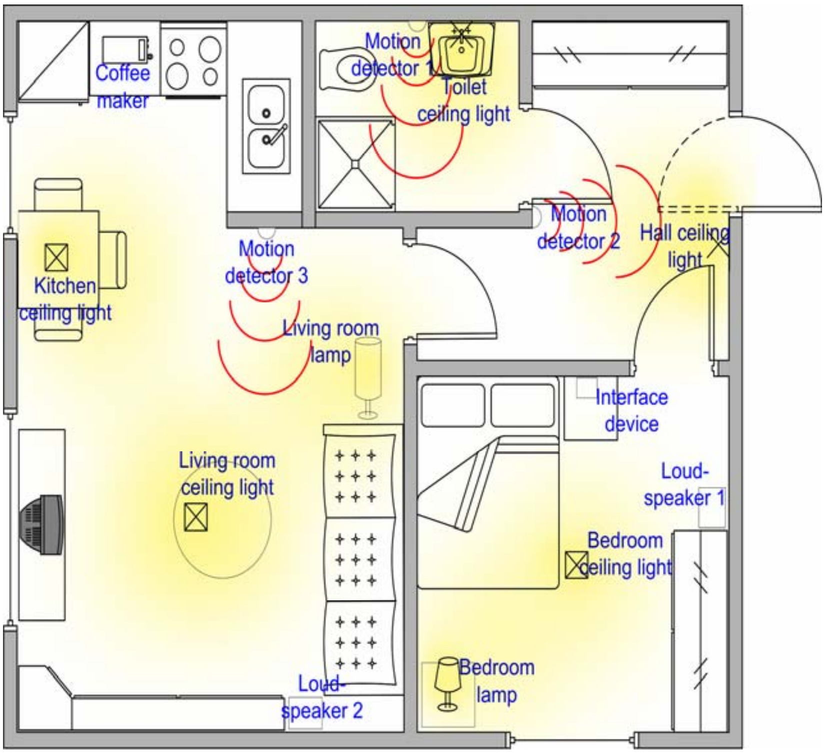

Figure 8. An imaginary floor plan showing the placement of devices attached to the proactive home system. The operational elements are named in the floor plan.

colors, soft textiles, and light wood furniture. Especially in the evenings or when people expect guests, they wish that the lighting of the home has a warm tone. In that sense, the home environment differs immensely from, for example, 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 centered on a hard technological, almost businesslike, element (see Jokinen & Leppänen, 2005). The visionary 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 the public and the actual appearance of today's Finnish homes. In our research, we sought to challenge this stereotypical image of smart homes and to look into whether bringing new functionalities to the home necessarily means that the atmosphere of the home has to change. We believe that new devices can give the user the feeling that these technologies are designed and intended to be used precisely in common, everyday home environments. This is an important perspective because, in our study, the interviewees were not willing to compromise the cozy feeling in their homes. Therefore, this was and should be taken into account when designing novel devices and smart services for homes.

In the beginning of 1990s, Mark Weiser (1993) presented the idea of ubiquitous computing. It is unlikely that our informants were familiar with the principle, yet, the attempt to embed technology was well known among them. The interviewees expressed the wish to have technology only if was implemented as embedded, unobtrusive devices, as is demonstrated by the following quote:

> *I definitely don't want here any evidence 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, the informants could accept technology more easily if it would follow the concepts of ubiquitous computing and calm technology. Because the idea of proactive computing suggests that people should be completely outside the control loop, the emphasis for designers and engineers should be to make such technology also embedded, ubiquitous, and calm. Screens and keyboard interfaces that are familiar from the world of interactive computing would multiply in homes, if they would also accompany the arrival of proactive home systems. In that sense, the requirements of calm, embedded computing should be met prior to developing proactive technologies into homes.

During the home automation study it became clear that reaching the optimum adjustment of lighting within the home environment was a much harder task than it seemed in planning. Even though the system already contained various regulations or adjustments in the bedroom, living room, and bathroom lighting, the actual controlling logic was not even close to the optimum when experienced by users in their living environment. These shortcomings of automation are due to numerous issues. For example, the distinctly different natures of various domestic spaces and rooms set varying requirements for lighting. In addition, the time of day, week, and year bring changes in the use of spaces and these would also need to be considered. Responding to such challenges, there are researchers like Mozer (1999) who consider that a smart home should always also be truly adaptive. 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. In our study, the participants occasionally felt the need to manually override the inappropriate behaviors of lights that were controlled by the automation system. The X10 system comes with a remote control intended for such purposes, but the users felt that this was just another unnecessary layer of technology because their homes were relatively small to start with and they usually could locate a regular wall switch more easily than a remote control that would often go missing. Some participants stated a preference for a room-specific adjusting point (e.g., a small touch screen) on the wall that would enable control of all the lights of the room from one place. However, this would also add screens and visible control technologies in an undesirable manner.

It also became apparent that the optimal placement of the motion sensors and lamps is difficult to know without experimentation within the home environment. People are rarely conscious of their or others' movement within the domestic space and the use of motion sensors activating lamps, especially in small apartments, can make this movement or simple body repositioning annoyingly obvious. Further, homes can involve areas (e.g., a balcony) that people want to be kept free of electric light, opting to be in darkness or in natural light without external lighting switching on whenever that space is entered.

The participants regarded as a most surprising or exceptional feature of the experimental home system its ambient sounds and how these sounds affected their mood. They brought out that the bird sound slowly growing louder had a positive influence on the atmosphere during the mornings and made the moment of waking 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 sound would be more efficient if it would include some sort of abrupt, irritating effect in the end. In regard to the retiring routine, some felt it annoying that they had to input the time for going to bed in advance, whereas others did not find any problem in it. The test setup also had the effect of imposing the same sleeping rhythm to all family members, which might have been experienced as a nuisance by some. In any case, the sounds were considered the elements that most changed the experience of the 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 at least one week, the prototypes started to become 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 a home interior helped make more visible the often elusive and ill-articulated dimensions of home life and domestic settings. Moreover, while 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 from their contemporary homes. Even simple lamps equipped with motion sensors can provide new experiences that reframe what constitutes a smart home.

In general, one should note that the user-centered study of proactive computing has its challenges. First, setting up a larger scale proactive system for the home environment presents substantial technological challenges since no commercial solutions are available to support complex or adaptive functionalities. Second, making these designs user centered often requires users' involvement to the degree that it may appear contrary to the basic philosophy of proactive computing, which aims to get humans out of the loop (Tennenhouse, 2000). There are no patent solutions for these and other such challenges at the moment, and we need more research that presents and tests models of life with humans and technological agents coexisting and cooperating in various combinations.

Approaches to Smart Home Design

The results presented next were produced by analyzing simultaneously the scenario study's data about the smart home concept and the interviews conducted after the test of home automation prototype. The two households involved in the home automation study participated also in the scenario study that was conducted the year before. During this process, different responses emerged when these people discussed the functionalities of smart home systems first in theory and then assessed the acceptability and suitability of such systems for their own homes in practice. 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 employ 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 emphasized that they wanted to keep control of their domestic spaces regardless of the conveniences the new proactive technology would make available. This sense of control was related to their sufficient awareness of the functionalities of the proactive systems. The border between a sense of control and obtrusiveness seemed to be a fine line, with the participants more highly valuing tranquility in their homes. In this sense, tranquility did not mean that it should be quiet at home but rather that the domestic space was represented as an area where one was able to be at one's leisure without worries about the technical infrastructure of the home. Tranquility was also related to a pleasing and well-planned interior decor. Although many participants liked the idea that domestic technology would be hidden under surfaces and inside furniture, some emphasized that they would not want to be reminded by the system's workings, that they were living in a home surrounded by invisible technologies. This concern was directed at the idea of the homedweller as the active participator or decision-maker in the smart home environment all the time (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 technologies that make decisions on their behalf, primarily because they felt the possibility for misinterpretations was 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 for these technologies to be acceptable, it should be possible to switch off the proactive system whenever needed or desired. They were also concerned about the accessibility of user support and help desk services after these systems have been introduced, large-scale, to the consumer market. Thus, the smart home was perceived as a rather big computer affecting the home rather than a place where one could live. Frustrations and problems they had encountered previously in the PC world evoked doubts that the home would work any better than a typical computer. In summary, this common view holds that the smart home is regarded as an unstable and obtrusive technology that one cannot trust in and control, feelings they currently do not have in a home free of smart technologies.

This view of smart homes could be related to the implicit notion that the interior of a smart home has a specific appearance. A few participants referred to the popular conception of the smart home full of flashing lights, small screens, and an interactive wall. A common notion of the smart home as an environment that looks futuristic, ascetic, cold, and too technical (see Leppänen, 2001) leads easily to the presumption that one cannot organize and freely change the domestic order because of the embedded computing technology. The approach was based on the idea that a smart home cannot look nice and be cozy, and that the technology inside a home constrains the interior decor. In this sense, the smart home technologies are perceived as the opposite of coziness, which is expressed by a particular look and feel of furnishings, color schemes, textures, and their physical comfort (see Garvey, 2003). This approach was seldom mentioned explicitly although some participants said that it is difficult to imagine invisible smart technologies embedded within the furniture and surfaces similar to those in their contemporary domestic environment.

> *Somehow… I think the home is just for the human, and to me this means that there are perhaps some candlelight and wooden materials, and softness [...]. But of course it can be that my notion [of technology] is a little bit stereotypical because apparently 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 within the domestic environment is in some way reflected in the appearance of the home interior. Usually this meant that the smart home was conceived with features that are familiar to people from current media technologies. From a design perspective there appears be a substantial challenge in how to communicate to the users of smart homes the fact that familiar domestic objects (sofas, pillows, tables, walls, floors, etc.) have some new, technology-induced affordances and control functions (Kuusela et al., 2005).

Another common attitude among the participants was that a smart home would make life easier. Most of the participants claimed a willingness to live in homes that facilitate or automate some predefined chores or routines. For instance, waking was seen as a fairly regular routine during the weekdays, and 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 (replacing the now common bleep of an alarm clock), and that would have coffee or tea ready for them by the time they are awake. However, differences emerged when the informants started to assess whether or not the curtains should open automatically before or during the waking period. From these comments, we can see the smart home technologies were regarded as making some dull routines more pleasant while increasing the flexibility of information and communication technologies around the house. An underlying idea was that smart home technologies enable enjoyment and conveniences that facilitate domestic life. This approach also involved the evaluation of the smart home as something luxurious, an unreachable fantasy that is nice to dream about but impossible to obtain for most people.

One negative association that informants attached to the smart home was the belief that it could make people lazier. Some 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 carried out while at home. They assumed that smart home technologies would involve many automated functions that would make decisions on behalf of the 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 and, in other words, make the people lazy. This line of thinking was based on an idea that when people become used to life surrounded by smart home technologies, their functional modes and mental capacities will become reduced. It should be noted that this view can be linked to the concept of technological determinism (Chandler, 1995), which suggests that technology inevitably influences humans, because people will adjust themselves to the new features and behaviors suggested by smart technology.

These above-mentioned approaches to smart homes emerged from almost every interview conducted during scenario and home automation study phases. They could be read as commonly recognizable conceptions that contemporary Finnish people interested in new technology used explicitly or implicitly as associated with the smart home. It was typical that the participants brought out both negative and positive sides of a smart home. Although all of these attitudes were identifiable in the informants' conversations, it did not mean that they always agreed upon all of the points included in the discussion above. Some participants brought out particular situations and exceptions that questioned the dominant perception. They also wanted to stress that the effects of new technology are often complex and some generally shared notions concerning forthcoming technology can change after personal experience.

If people adopt and purchase proactive domestic technologies, it is evident that it will change their domestic lives. But it is equally likely that people will modify the technologies, domesticating them into their homes and innovating new uses for them. Commonly, the smart home is understood as a mixed-use environment in which residents still have some visible terminal devices. When discussed from the perspectives of calm and embedded technology, which means that computing resources are distributed and hidden in microprocessors within domestic appliances and furniture, the idea of a smart home seems to be more easily accepted among users. They are, after all, already living with numerous, ever-increasing variations of home electronics, and can tolerate their presence to a certain degree. However, people also have pieces of furniture that they want kept free of any embedded technology. For example, some participants mentioned rustic style furniture or antiques as artifacts that they would not want spoiled with embedded computing technology. The invisibility of electronics, in itself, does not make the home environment calm if issues such as furnishing preferences, household compositions, or social use contexts are not sufficiently considered.

THE MAIN FINDINGS: FACING THE CHALLENGES OF PROACTIVE TECHNOLOGY IN HOMES

The methodology of this research already has provided beneficial lessons: Setting the home as the context for research and maintaining a long-term contact with the informants through various iterations of research create fruitful environments for interdisciplinary research and innovation. On the other hand, the selected methods required substantial researcher resources and a wide combination of competencies, as it involved work at the theoretical, methodological, and implementation levels that draw together the strengths of the human sciences, art and design studies, and technology research. The initial set of proactive technology design principles (see Table 1) still appear as valid conclusions, even as we must emphasize that there are common design principles for furniture and other home elements that need to be taken into account, not the least of which is that proactive homes would continue to function in their traditional residential roles. However, the results highlight further challenges that proactive technology faces when being implemented in homes.

One of the general findings of our research is that the home is a sensitive environment where people often hold rather conservative attitudes towards smart technologies. This can be partly explained by the visions of the smart home technologies in the media and popular culture. The idea of smart home typically is associated with a futuristic and ascetic interior in which display walls and other very visible technical elements dominate the space. Because of that image, it is difficult for many people to imagine smart home technologies that are not intrusive and, to some extent, invisibly embedded within the home interior, changing the look of their contemporary homes in only minor ways.

On the other hand, people’s notions regarding their awareness of a proactive technology’s functionality are typically contradictory: Once they have accepted that functionality, they want to maintain full control of their domestic space while simultaneously not wanting to be aware of the constant sensing and gauging actions of the system. In order to increase a sense of control, the system should offer its users some sort of log files for checking what it has done, as well as alternative setup options and installations if users are not satisfied with existing ones.

Another important finding is that when access to and interfaces for the advanced and internally complex technologies are provided via familiar, comfortable, and reassuring designs, the social acceptability and usability of the technologies in a home context are clearly enhanced. Therefore, domestic technologies with diverse designs must be offered because decor preferences vary. When embedded computing in furniture becomes more common, both the design of the furnishings and the usability of the technologies will be key factors in domestic acceptability.

One promising research direction that may lead to successful integration of smart technologies in homes is that of animistic decor elements, meaning an approach into future home design where cushions or other soft and familiar home objects are seemingly “brought to life” and given some degree of personality through 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 dystopian fictional stories that display the ambivalence and distrust many humans hold towards intelligent machines (Mäyrä, 1999, p. 209). The simple interactions with a smart pillow or other familiar home elements embedded with technologies may offer a necessary counterbalance towards these initial fears or lack of trust.

Our research appears to demonstrate that the control of lighting and sound with motion or sound level sensors is mostly acceptable, as long as people retain a sense of control over the behavior of technologies in their living environment, in our case via traditional backup interfaces. However, differences in interior spaces and household compositions should always be taken into account when devising functions that are activated by various sensors. For example, in small homes with more than one dweller, lights based on motion sensors can be perceived as obtrusive if they switch on and off too often. Therefore it is beneficial to think carefully about where to place such light functionality and to always test the appropriateness of the locations of sensors and lamps before installing them. Introducing sound sensors to the living environment was also faced with a mixed response. For example, while many families living in apartment buildings liked the idea of having visible information about the sound level of their environment, other families considered sound level information unnecessary and questioned the whole idea of integrating a decibel meter and a table lamp. Of course, there might be much more capable proactive home technologies available in the future to address this area, such as proactive noise cancellation systems. Such developments, again, need their own user-centered studies before they are commercially introduced.

CONCLUSION: RESEARCHING FOR THE FUTURE

The role of smart technology is unlikely to stop its advancement in homes. We believe that as future generations of homeowners become increasingly technologically savvy, they are likely to welcome additional functionalities into their homes. Still, our research uncovered substantial resistance towards smart homes. Our subjects voiced concern about the potentiality of their homes no longer being sites of relaxation and shelter from the world, but rather becoming increasingly complex, needing endless updates, and facing periodic malfunction, causing increasing unreliability and user stress associated with information technologies. Therefore, the technologically robust, fail-safe, and nonintrusive character of smart home technologies is a key priority.

We also found that some functionalities in homes are currently more feasible for proactive implementation than others. For example, ambient elements, such as air conditioning, heating, security, and, to a certain extent, lighting and ambient sound, are features that inhabitants have a rather low threshold for delegating to proactive technology's control. However, our informants were skeptical about the potential of smart technology taking a strongly proactive, intention-anticipating role in their personal lives. When a particular real-life situation needs to be interpreted and reacted to in a correct way, even knowledgeable humans such as family members sometimes have problems in deducing the right way to act. Misunderstandings are a common part of human life. Whether people would indeed be able to accept such applications if the technologies actually were accurate in their predictive operations remains for future research to solve. Using a team of professionals operating a specifically rigged house remotely and covertly would be a "Wizard of Oz" approach (Gould, Conti, & Hovanyecz, 1982) into studying human-level intelligence as experienced in a proactive home setting prototype. But this kind of research, of course, would include its own considerable challenges.

The main derived lessons for research practice focus particularly on the necessity of interdisciplinary collaboration and multiple methodologies if changes to and developments in technologies are investigated. A study that utilizes only interviews as its method, for example, and tries to deduce some conclusions about the acceptability of future technologies from informants who have experienced only current technologies is inherently unreliable. The preconceptions of the subjects and various popular ideas will have a dominating effect on results of such a study. But if human science researchers, designers, and engineers work together to realize some concrete experiences of such future technologies for users, and the users have enough time to live with these technologies and thereby domesticate the prototypes as parts of their lives, then the results will have much more relevance for all parties involved. (For a fuller explanation of the domestication of technology, see Pantzar, 1996, and Silverstone & Hirsh, 1992.)

The subject of proactive technology has proved to be a complex and controversial issue to study. Methodologically, it was challenging to investigate because the phenomena needed are indisputably intelligent services that would be able to deduce human needs and intentions and thereby genuinely anticipate and take action in a proactive manner on our behalf. Yet, most of these intelligent services remain beyond the capabilities of current state-of-the-art information technologies. Rather than attempting to implement such high-powered computational systems, the research goal here was focused on the human interface and coexistence of humans and "living" technologies in the context of real homes. Embedded processors, sensors, and network capabilities were applied to everyday objects such as pillows, lamps, and alarm clocks in order to learn more about the acceptability of various smart functionalities, the relation between design and technology within a home context, and about the applicability of our methodology. From a research angle, the results appear promising, and apparent benefits are to be gained by involving real users in the different stages of a research process, both as informants and codesigners, by inviting and eliciting their ideas for the potential applications of emerging technologies. The combination of cultural probes, scenario studies, minidesigns, and implemented prototype systems provided the interdisciplinary research team with a suitably wide set of tools from which to derive rich data and to build the basis for knowledge and theory formation.

For a developer or designer of smart technology, the lessons of this research particularly focus on the proactive home technology design principles and their underlying case studies that we have created during our research. It would be most welcome to see examples of industry approaches where the users' key priority of "feeling homey" that we have reported here are implemented as the driving principle for smart home designs. A different kind of finding is derived from a more action-research-oriented angle. As the informants became more familiar with the opportunities offered by contemporary home technology during their participation, one family actually decided to purchase and install a home automation system. Thus, in at least one case, the participation in research led to changes in informants' lives. In more general terms, the increasing speed of the development and complexity of home automation and electronics has raised an apparent need for a "home technology consultant," who would help people to make informed decisions, based on their unique needs, about which technologies would be genuinely valuable in their case.

There is also a 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. The possibility exists that, without public discussion and proactive measures by means of recommendations or even regulations, there might be developments that are either unethical or provide various 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 to actual users, both on the technological and regulatory levels, regarding the development of new technology, and involve them when deciding on the directions and uses of these technologies for the future. The consequences, after all, are going to influence everyone in the society.

ENDNOTES

1. Quotations are cited with the informant's gender and age. All interviews were conducted in Finnish with native-speaking Finns. Informants' quotes have been translated into English by the authors.
2. The lamp is a model from IKEA, an international chain of home furnishings.
3. X10 home page (2006). Downloaded August 24, 2006, from http://www.x10.com.
4. MisterHouse home page (2006). Downloaded August 24, 2006, from http://www.misterhouse.net.
5. Perl is a programming language that has become particularly popular in implementations of different Internet services; see http://www.perl.org/about.html.

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