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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