Morphome: A Constructive Field Study of Proactive Information Technology in the Home

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ABSTRACT
This paper presents the main results of a three-year long field and design study of proactive information technology in the home. This technology uses sensors to track human activities in order to proactively anticipate the direction of human activity. With it, it could be possible to build an environment without buttons and remote controls. However, the home represents a series of design challenges for proactive technology. This paper describes how we have identified suitable areas for proactive designs with user research, how we built several "minidesigns" and experience prototypes, and how we tested them in a series of five field studies in the Tampere and Helsinki regions in Finland. The paper ends with a section in which we outline some of the main design principles learned in these studies, and point directions for studies in the future.

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Proactive technology, ubiquitous computing, home, field study

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI).

PROACTIVE TECHNOLOGY AT HOME
One trend in information technology has been towards ambient designs. Words such as ambient, augmented, and ubiquitous technology try to give names to these trends that have their basis in not just in advances in information technology, but also in changing consumer tastes [1,2,3]. Although there are variations in what these terms mean, they all denote technologies that disappear into the environment: they enhance it, embedding functions such as memory and media content into the material environment. Perhaps most typically, these applications have focused on media and other types of digital entertainment.

As David Tennenhouse [4] has defined it, proactivity not only provides a solid diagnosis of something happening in information technology, but also a productive design philosophy. What makes the notion productive for designers is that it may provide solutions for important design problems prompted by the integration of information technology to our material and human environment. In technological terms, this notion combines data processing, communication, content, and real world design. As we move towards ubiquitous technologies, intelligence gets built into things around us – it disappears from sight and attention, fading into the periphery. Sensors are used to measure human activities and to predict what humans are doing; technology reacts to ensuing lines of action before they take place. Unlike interactive technology such as the PC or the mobile phone, proactive technology responds to human action and makes predictions of it without a human in command.

The shift from the traditional notions of interactivity to proactivity [5] provides a solution to what can loosely be called "a button craze" – think about a home with hundreds of electronic devices, all controlled using the interactive paradigm. Taking humans out of the loop through proactive designs is an obvious, and attractive solution to this problem. At best, proactive technology might help to resolve the problem in "smart homes" that, despite long history of promises and research, can still be described as a technological dream rather than reality [6,7].

However, the flip side of the coin also exists in particular when we design things for the home, which is a very specific environment. In one word, the home is a sacred environment: people expect control over things in their home. This is easily lost in proactive technology: when conventional existing things are assigned new functions, it is not at all clear that people understand them, or are willing to delegate activities to them. Even if single devices might be relatively easy to learn, how about increasingly complex system responses to

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complex human intentions, embodied action routines, and social activities?

This paper explores the intersection of proactive technology and home, asking these questions.

- What things are people willing to delegate to proactive systems?
- What kinds of technical and design issues ought to be taken into account when designing proactive technology?
- What happens when we start to think of proactive technology in terms of information systems, connected by either centralized or distributed intelligence instead of individual devices?

To answer these questions, we present an explorative, multidisciplinary, and user-centered study of proactive technology, Morphome, which has been conducted in the Tampere and Helsinki regions in Finland in 2003-2005.

THE APPROACH: A CONSTRUCTIVE FIELD STUDY

When studying the notion of proactive technology in the home, we decided to build on two strands of research: constructive research, and an interpretive field study.

Constructive research. The constructive part was necessary simply because proactive technology does not exist in the home, which means that in studying it with diaries and interviews, cultural facts might seriously confound the results. Proactive technology is "slow technology" [8]: it is difficult to understand and learn:

- In addition to personal computers, one of the few places in which one finds illustrations of proactivity is science fiction, which is mostly dystopic, with well-known movies like *Space Odyssey 2001* as the trailblazers of this genre. A realistic understanding of technology and its possibilities is not just missing, but schemes from media may tends to exaggerate its technology-gone-wild aspects.[9]
- The second confounding factor is that people easily think about this technology using categories of ordinary life. For example, people easily understand proactive chairs as furniture and act with them as chairs rather than as pieces of technology.

Consequently, to study proactive technology, we need to give people an experience of that technology. To that end, we need to build devices and environments that have at least some proactive features, and give them to people. These people can use and explore them for long enough so that they do not just focus on it as a novelty, but as a routine part of everyday life [10]. Such constructive part makes it possible to follow how people explore this technology, and develop routines for it. Background experience created over time gives a more realistic view of proactive technology. The results from field studies can be used in improving technology. The design process is a cycle of long-term user studies conducted with technology with iteration in mind.

Interpretive field study. The second driver of our approach is that we need an interpretive approach to study experience. Recently, Forlizzi and Ford [15] presented a model of user experience in interaction. For them, experiences are momentary constructions that grow from the interaction between people and their environment. Experience fluctuates between the states of cognition, sub-consciousness and storytelling depending on our actions and encounters in the world. Experience is something that happens all the time: sub-conscious experiences are fluent, automatic and fully learned, cognitive ones require effort, focus and concentration. Some of these experiences form meaningful chunks and become demarcated as "an experience.". Through stories they may be elaborated into "meta-experiences." More recent developments of this line of thinking [see 16] have argued that experience takes place in social interaction [17].

The interpretive approach had an important implication for methodology. The field studies were not designed as "tests," but as starting points for following what kinds of social responses would develop over time. In designing for homes, we kept these things in mind:

- Any realistic understanding of technology at home requires that it is studied in a realistic social setting involving several people. The use of technology is a social process in which people borrow opinions and interpretations from others, constructing their lines of action together with other people [11]. For instance, aesthetic considerations as well as issues related to usability may change as a function of social action. What seems ugly one day may appear beautiful on another, if one's fellows appreciate it.
- Technology needs to be studied in real homes. What people accept into their homes depends not only on individual devices, but also on what they have at home already. The history of the home goes beyond technical devices and compatibility into issues like what are the most meaningful places at home.
- An important aspect of how people relate to technology relates to its design features. For example, style often dictates what people accept to their homes [12]. To give sufficient weight to design, we build on a paper by Steven Kyffin from Philips Design, and Loe Feijs from the Technical University of Eindhoven. They talk about "mini-designs" that have "sufficient aesthetic and technical qualities to attract users and let them work or play with the design." Minidesigns are not models*:* they really work. Also, they differ from traditional prototypes in that are built to test only one aspect, for example technical feasibility. [13, p. 11].

For these reasons, we chose to conduct a series of empirical studies at real homes instead of building systems into laboratories, or into smart homes run for experimental purposes. The method has its origins in Buchenau and Fulton Suri's [14] notion of experience prototyping. For them experience prototypes are representations

> designed to understand, explore or communicate what it might be like to engage with the product, space or system we are designing... When we use the term "experience prototyping" we are talking about methods that allow designers, clients or users to "experience it themselves" rather than witnessing a demonstration or someone else's experience." [14, p. 424-425].

The main difference to experience prototyping is that experience prototypes are built to illustrate concepts, and tested over a fairly short period of time. Taking the cue from slow technology, we have consistently given people time to explore technology and make it meaningful.

Finally, Morphome has combined the efforts of a multidisciplinary team. Our engineers have been building devices and systems. When we have not been able to construct technology, our designers have created scenarios in interviews to make the proactive technology more concrete for users. These scenarios have placed our devices into a specific material, social and technical environment [18]. Minidesigns, experience prototypes, and scenarios make the experience concrete and tangible by creating an environment that produces and maintains a rich context in the interviewee's mind when he talks to social scientists about minidesigns and experience prototypes.

DATA AND METHODS

Morphome has proceeded in three phases. In the first phase, we studied a series of homes in the cities of Tampere and Helsinki, both in Finland, with a probes methodology to learn which areas of home life could be suitable for proactive designs. In particular, ambience – sound, lighting, odor – came out as suitable topic for subsequent work. In another study of this phase, we created a minidesign from a pair of cushions partly for testing wireless technology and the robustness of the technology, partly for getting an initial idea of whether a simple proactive technology would make sense to people at home.

In the second phase, we first built an Ikea style lamp minidesign with several functions that mimicked proactive behaviors, such as changes in light intensity over time. In another lamps study, four lamps with varied designs were built to see whether design makes a real difference. These studies are explained in more detail below.

In the third phase, we built an experience prototype of a proactive system. Two real homes in Tampere were augmented with sensors and programmable behaviors using the X10 home automation system (www.x10.com), which uses existing electrical power lines for communication between devices. However, the commercial software of X10 was rigid, and we replaced it with open source software called Misterhouse (MH; www.misterhouse.net). MH combines the X10 hardware with a PC and offers a simple user interface as well as some basic means for programming and necessary object libraries. The logic of events and functions were programmed in Perl.

Study	Description
Probes	Spring 2003. A probes package was sent in six homes for 10-14 days each. Closing interview with collages.
Cushions	Summer-Fall 2003. In three homes, one week with a technological prototype in each. An optional video camera. Closing interview.
IKEA	Summer-Fall 2004. A four-week study with one lamp in four homes, plus a closing interview with technology scenarios. We also conducted scenario interviews in 12 other homes later.
The Four Lamps	Spring-Summer 2005. A four-week study with four lamps in four homes. The closing interview with technology scenarios. Weekly intermediate interviews.
X10	Summer 2005. A two-week study in which X10 was installed into two home.

Table 1. Summary of homes studied

All studies were user-centered, conducted in 19 real homes with prototypes, and in additional 12 homes with scenarios interviews. In all, 65 people participated in our studies. Their average age was 28 years (with children removed, 32 years). In a five-point scale, we estimated that the participants' socio-economic status was on average slightly over 2 (Mean=2.1). Without students, whom we classified to the lowest category (1), the figure arose to 3 (Mean=3.1), with a range from 2 to 4. In selecting participants for our studies, two principles were followed. First, we selected acquaintances of acquaintances to avoid leaking information about our aims to participants. Secondly, with two exceptions in the probes study, which required visual imagination, we discarded designers. As Table 1 shows, the design work was iterative. There were three phases of research: the pilot study, the two studies with light as design material, and the X10 proactive system prototype. After each main phase of research, we withdrew from fieldwork, and went back to the design table and electronics laboratory. All interviews with users have been transcribed *in verbatim*.

In our user study, we have followed an interpretive procedure typical to qualitative social sciences and in that we went beyond the traditional usability paradigm [19]. Although we have studied a technological vision by building minidesigns, our study has studied this vision through user responses. From the pragmatist perspective [15, 16, 17], human action is always tied to specific evolving lines of action and life circumstances. Therefore, we analyze our user data by explicating variations in human perspectives articulated to us rather than by testing a set of predefined hypotheses. The analysis proceeded by searching for statements from transcripts of interviews, photographs, and from other data, making a collection of these statements, and then classifying this collection into main variations.

THE PILOT STUDY: PROBING HOMES AND TESTING RFID

Outi Liusvaara, a Finnish artist, once counted all things in her home [20]. In her artwork, she listed 6168 objects from her studio. This figure shows that for any proactive design effort, the mere multitude of things at home is a challenge. How to select promising areas for design from such a wealth of objects, each having different forms, colors, and functions? To answer this question, we conducted two pilot studies, a probes study and a prototype of a cushion

The Probes. With probes, we tried to identify suitable design objects: ambience vs. intentionality. Hypothesis was that since humans are notoriously bad in making sense of complex intentional action, people would not like to rely on technology that builds on such notion – but that they might accept proactive technology on other areas of life.

To produce qualitatively driven data that would also be suitable to inspire our design, we did a probe study [21, 22]. As we were interested both in producing a qualitative understanding about people's relationships to homes and home technologies, as well as deriving starting points for future proactive technology designs, we modified the original probes method. When the probes were returned from homes, they were analysed and reflected upon both in design workshops among the research group, but also in group interviews where the interpretations were discussed with the informants themselves.

Figure 1. The probes package and a floor plan drawn by an informant. The affective characters of home technologies are revealed with animal figures.

The results from the probes study pointed out that ambient environment is a promising area for designing proactive technology. People did not want to let technology into critical systems, and they did not want it to second-guess their more complex intentions like the choice of music or TV programs. This result corroborated our theory: analyzing human intentions with algorithms is probably impossible, if we talk about complex intentions and meaningful processes that drive them. Many intentions are not voiced. Also, they break, are reshaped, and renegotiated [23].

The Cushion Study. To test technology, we built two toy-like cushions and bean bags that kept noise when they sensed the presence of another cushion. The cushions had a microcontroller, and they communicated with an RFID reader. The system was placed in three homes, each with two parents living with two small children.

For these families, the cushions became emotional companions, secretary-managers and homely reminders. Unsurprisingly, the children became quickly fond of the cushion and they approached it and the tags open-mindedly and experimentally. In contrast, the parents found the prototype puzzling. It did not seem to be a good toy, and although it was interactive, it was not very good as a learning tool either. Some parents just accepted it as "a special cushion." [22, p. 107-110].

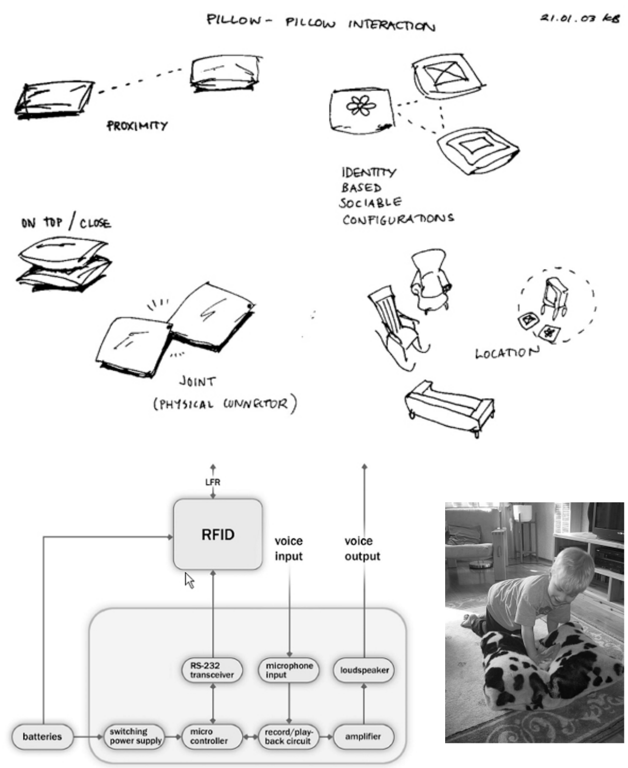


Figure 2. The Cushion Minidesign. Design sketches studying cushion-cushion interactions, technical description of the cushion minidesign, and a child playing with the actual cushion.

Technically, two main results emerged. First, experimenting with radio frequencies and protocols proved that the cushion, seemingly simple as it is, provided already several engineering challenges, especially with protecting antennas and due to RFID functioning in a limited range only (approximately 50 cm) [24]. Secondly, we noticed that power consumption became an important issue. It was relatively easy to install a battery large enough for a week's study into the cushion, but a scenario of a home with lots of rechargeable devices proved to be cumbersome. Most homes today have anything from 10 to 20 electric devices that need to be recharged, which is a bother already. Building a home with perhaps 50-100 electronic devices that have to be recharged would make it unworkable. For this reason, we decided to get wired for the next phase. Also, more meaningful response than sound had to be found.

AMBIENCE: LIGHT AS MATERIAL FOR MINIDESIGNS

In the next phase, we decided to focus on using light as design material at home. Light has several benefits as design material. It is typically ambient, its physics is known, it is challenging for designers, and it is meaningful for both children and adults. Our two lamp studies aimed to elaborate and validate results from the pilot studies.

The IKEA Lamp Study. In the first study, we chose to play safe in design, and selected a conservative design style. This language is what most people associate with modern design. The design was an IKEA style lamp that reacted to sound in four ways. (1) A normal lamp with button for adjusting light; (2) a 10 minute cycle in which colors changed from warm to cold; (3) a sensor designed to keep light constant in the lamp's surroundings (4) a state in which red and blue LEDs reacted to sounds. It was also possible to attach other electric devices to the lamp. The lamp had four 36 W fluorescent tubes (2 colored, 2 normal).

Based on our earlier findings, we decided not to build complex software into the lamp. Instead, we used a simple sound sensor with responses varying depending on the time of the day. Further, we supplemented our study with scenario interviews. We embedded the lamp designs into a scenario describing five types of context. Scenarios were ordered from simpler to increasingly more complex. The first scenario started from the IKEA lamp. Subsequent scenarios placed it into increasingly complex social and technological environments.

People accepted the IKEA design to their homes, which corroborated the earlier finding from the probes and the cushion study – that ambient elements of the home provide a suitable area for proactive technology. However, people did not report noticing significant changes in the behavior of the lamp, even though they should have been easily observable from a physical standpoint.

S & H: Yeah, I didn't really notice it because the change was so small. It wasn't easy to perceive... the slow change of the system was pleasant, you could notice that something happened but it wasn't really vigorous. I think it was good too. My friends did not notice anything either.

Because the change [in the lamp's behavior] was so small, it wasn't annoying. Instead, in a sort of funny way, it was a nice thing. I didn't really pay attention to it, though I noticed the function. Perhaps it was just because of this feature that I kept it on.

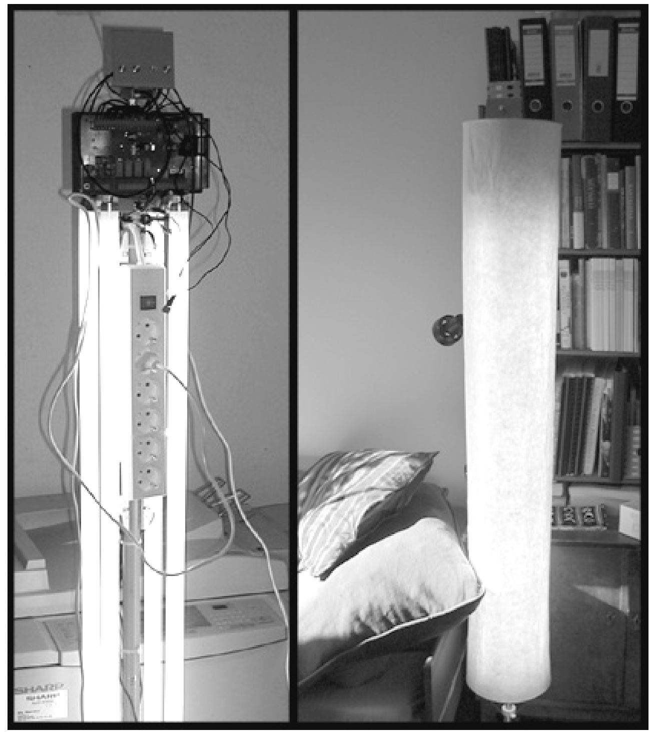


Figure 3. The IKEA Lamp Design: electronics and its states. The UI is the upper part of the left picture.

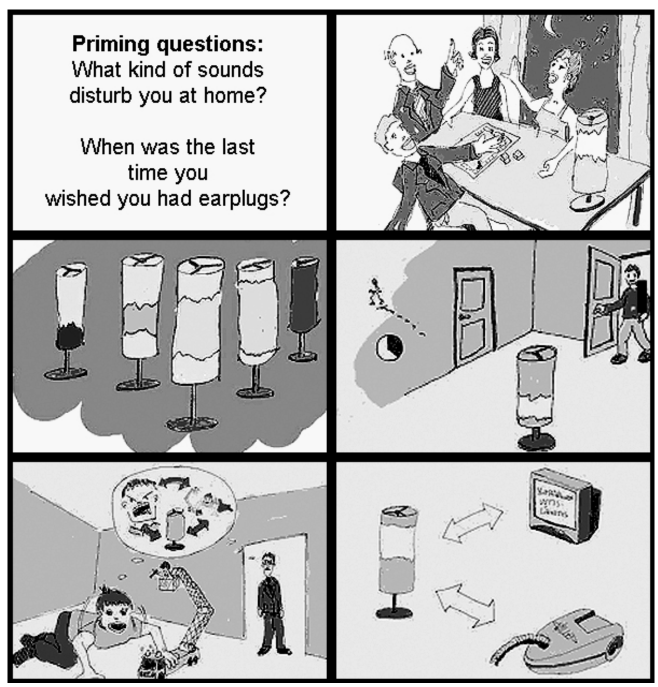


Figure 4. Examples from Scenarios. Up: the priming question sent a week earlier, the sound world of the home (preparatory question); Middle: the lamp reacting to sound, *Memory Trace* (lamp that remembered who had been in the room, and communicated that to newcomers); Down: the lamp in social context, the lamp as a control to other technology.

In other words, the design was seductive, prompting a methodological problem. We wanted to give people a peripheral understanding of new technology built into lighting, but there was little evidence of such awareness.

The problem may be related to the basic design solution. Changes in light may have been too slow to be easily recognizable. Another possible problem was design-related. If people have a strong culturally based idea on, say, how certain types of free standing floor lamps function, it may be difficult for them to register behaviors that depart from these ideas. Our conclusion was that design ought to offer the user something that tells him that there are new types of functions, or they remain little or even unexplored.

The Four Lamps Study. To get further at design issues, we conducted another lamp study. While in the IKEA Study, not just light, but design was ambient, this time we created four lamp designs that were designed to call forth attention and raise awareness of technology. Some of these designs were close to traditional taste, while some were far more distinctive.

To eliminate a possible confounding element in the IKEA study, we also made the lamps react to sound faster. These lamps reacted to sounds by changing colors from blue to red trough green color according to the volume. The blue color marked silence while red indicated the highest noise level. The changes between the colors took place smoothly even though the response of the colors changes was real-time. The lamps had a normal on/off switch. When they were on, they were always on the "proactive mode." Only the Ikea lamp could be used also as a normal lamp, i.e. the proactive behavior could be switched off, though people preferred to keep it in its proactive state.

In the Four Lamps Study, people did pay attention to these various designs, and in response created elaborated opinions about their designs and about their functions. For example, here people refer to lamps reacting to sound levels:

A: What would you think about an idea that some object at home would give you feedback about the sound level of the home?

E: Wasn't that the idea in the lamp (laughs)

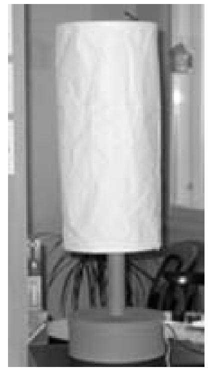
A: Yes, it was.

E: I had a crush on it... so that for instance if you could with lights or something else [get feedback, authors addition], it would be really nice, not a necessity, but a nice additional feature

I: Me too, I thought it was an exhilarating idea, and interesting. I'd take it with interest

Even though in general, people placed the lamps to the most traditional of places, next to TV (Figure 6), some of the more wild designs found their home base in other places. For example, as Figure 4 shows, the Giger lamp in one home was placed next to other tortured, twisted human figures. People experimented and negotiated about where to put the lamps, depending on their appearance and suitability to certain places in homes. Not just functionality, but also aesthetics and emotional attachment played a role in the process.

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



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

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

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

Figure 5. Designs in the *Four Lamps Study*.

In technological terms, the two lamp studies were far more successful than the cushion in the pilot phase. There were no problems in sensors or in output, and electricity became trivial. Also, the system was technologically simple, consisting of independent lamps that did not communicate with each other. This modularity made programming far simpler, and easy to understand for people. Finally, the decision to focus on light and sound simplified design as well. Focusing on light proved to be a good solution: when technology is embedded into systems that have already become a part of the fabric of modern living – for instance, light – there is no need to prove the value of a new design anymore.

Figure 6. **The *Granny* lamp in one home.**

EXPERIENCE PROTOTYPING PROACTIVE SYSTEM: DESIGNING FOR SEQUENCES OF ACTION

The final study, called X10, continued the earlier focus on ambient lighting, but embedded the results into a more complex activity environment. The basic functionalities of the system were lighting control, and routines assisting in waking up and going to sleep. These were performed by adjusting the lighting level of the house according to the time of day and recorded motion sensor information. In addition to light, ambient sound was used both in the morning and evening. The X10 study was devised to correct for the main problem in The Four Lamps Study, in which lamps functioned independently from each other. In X10, they were programmed to function as a system.

In this study, we programmed closely two sequences of action to learn about how people would make sense of a proactive system that responds to their activities through a time-ordered sequence that controls the behavior over several electronic devices. The "going to sleep" sequence was the more experimental part of our set-up; the concept was based on premise under which future home technology will adopt a more strongly proactive stance also towards the health of users. The operation of the wake up routine starts 15 minutes prior to the wake up time (at "Preliminary State"). The desired time is set by the user before going to sleep. It is also possible to use previous wake up time set the day before. The routine increases lighting and sound volume calmly so that by the wake up time, they are at 50 % of their maximum level. It can be turned off any time by the user by pressing the switch-off button in the "alarm clock" interface. In the case that the routine is not stopped within 10 minutes after the wake up time, the lighting and sound will slowly start to fade away ("Fading State"). (Table 2).

State	Function
Wake-up activated	The wake up time has to be programmed prior entering the state. The wake up routine is ready to be started as time condition is filled.
Preliminary state	The wake up routine will start as the state is being entered. The bedroom lamp and the living room lamp brighten linearly in 15 minutes up to 50% of the maximum. Ambient sound is played in the bedroom and in the living room. The volume is first low, but increases slowly up to 50% of maximum.
Running state	The coffee maker is switched on. The lighting of the bedroom and the living room, and the sound volume are further increased up to the maximum level.
Fading state	The lighting power of the bedroom and the living room lamps, and the sound volume level are decreased slowly.
Snoozing state	When this state is being entered, lights and sound fade. When the program jumps to the beginning of the wake up routine, and lighting and sound volume levels are increased. Snoozing state is on until the snoozing timer is expired.
Wake-up deactivated	The bedroom and the living room lamps, the coffee maker, and all sounds are switched off.

Table 2. The operation of the wake up routine in each state is explained. The purpose is to brighten the lights slowly and to offer a convenient environment to wake up in.

The lighting of home was adjusted according to motion sensor information. The time of day also affected lights in the toilet and in the hall. In the daytime, the lamps are brightened to their maximum. In the night-time, the lamps are brightened only to half of the maximum power. The purpose was to avoid the blinding effect as the user, accustomed to darkness enters a brightly lit room and begins to wake up. Figure 7 shows the placement of devices in one studio studied.

In our interviews, people confirmed that they wish to have embedded, unobtrusive devices, as in the following quote:

A: I definitely don't want to have in my home more things that remind me about technology. Maybe I could accept it if technology could be somehow hidden or so tiny that it would be out of my sight. (F, 33).

Our informants accepted technology more easily if it followed concepts of ubiquitous computing and calm technology. As the idea of proactive computing goes even further compared to ubiquitous computing, making it calm is also important [3].

However, even though we programmed only two routines into the system, we realized quickly that only the waking up routine was acceptable. The going to sleep routine, on the other hand, was thought as silly and unnecessary, as the following quote from field notes shows.

> Excerpt from field notes (June 7, 2005):
>
> S commented that for him, the falling sleep routine was unnecessary and even frustrating. It is silly to assume that people should know five minutes before they go to bed, and that they then put the sleep function on, quickly brush their teeth before going to bed... V. told that in her home, she and her husband did not set up the system in anticipation to going to bed, and that with this function:
>
> "The line between patronizing was crossed here (laughs). I don't want to a system to tell me when I must go to bed. I know when I want to do that. The function that reminded me about it was unnecessary."
>
> She added later that sound as such was relaxing and OK, but she doesn't want a technical system to tell when she is sleepy enough to go to bed.

The problem is that even such a seemingly simple thing as going to sleep is a complex achievement that is different every night. When people decide to go to bed depends on their mood, things in television, what they are doing, and many other things. Furthermore, even the very process is complex enough, consisting of different acts ordered differently daily. It is easy enough to anticipate that people brush their teeth every night before going to sleep, but how about using dental floss? Or when does the sequence start? Are there preparatory activities that regularly take place before the actual decision? Where should the limit of proactive guesswork be placed? Human action is fuzzy for people when they are doing things; it is often only in retrospect by inspecting the outcomes that people realize what they were doing.

Thus, although the basic idea of proactivity was welcomed, we also observed several complications of interest to designers. In addition to the fuzziness of action, we would like to point out these things:

- Reaching the optimum adjustment of lighting is much harder than it appears to be. Even though the system already contains different adjustments for various rooms, it is not even close to the optimum. For example, the time of day, week, and year need to be considered, not to mention variations in, say, moods.
- It is difficult to optimize the placement of the motion sensors and lamps without trying them out in the real home environment.
- People are not always conscious of movement in the home. However, the use of motion sensor lamps can make them annoyingly aware of others' movement.
- Homes may involve areas (e.g. a balcony) that people want to be kept free of electric light. They should be able to be in darkness or enjoy natural light regardless of programming in the system.
- The participants were surprised about how ambient sounds affected their mood. They discovered that the sound growing slowly louder had a positive influence on the atmosphere especially in the morning.

These observations raise the question whether the smart home should always be truly adaptive, as suggested for example by Mozer et al. [25]. Central to the concept of an adaptive home is that it observes the lifestyle of the inhabitants and adapts its operation to accommodate their needs. The participants also felt that the use of remote controls together with lamps is unnecessary because the distances in their home interiors are fairly short and because a common problem with all remotes is that they often go missing. Some participants suggested that they would like to have a room-specific adjusting point (e.g. a small touch screen) on the wall that would enable controlling all the lights of the room from one place.

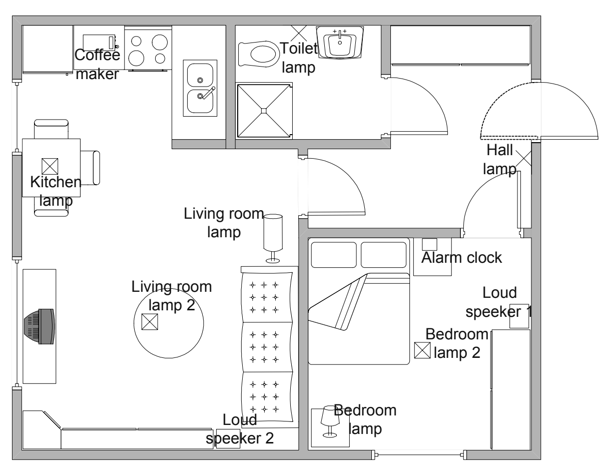


Figure 7. Floor plan showing the placement of devices attached to the proactive home system. The operational elements are named in the floor plan. Details are changed for anonymity.

Many of these issues go back to the complexities exhibited by human action. Our conclusion was that it is better to target ambient things with relatively simple systems rather than to support technologically truly complex activities.

DESIGN PARAMETERS FOR PROACTIVE TECHNOLOGY AT HOME

Proactive technology holds a major promise that is definitely worth exploring also at domestic places. Proactive technology also provides an exciting starting point for redesigning homes of the new century. The opening section outlined three questions for this paper:

What things are people willing to delegate to proactive systems.

- When designing for proactive technologies to home, the focus ought to be on ambience, not on second-guessing complex intentions or social action. There are other productive areas, too, but our study has focused on ambience.

What kinds of technical and design issues ought to be taken into account when designing proactivity

- *Design*. Above all, design matters. When intelligence is embedded into ordinary things, our study shows that design's significance can hardly be overestimated. Since people use ordinary cultural models to evaluate ordinary things, and bodily routines to relate to them, aesthetics and ergonomics matters. We ought to move from prototypes to "minidesign." The IKEA example shows that design can be too successful up to a point in which people do not define things as technology, but as furniture. The Four Lamps Study showed that to give people peripheral awareness of technology, we need to adjust designs accordingly.
- *Technology*. Our suggestion is that it is advisable to keep proactive technology at home relatively simple by measuring things crudely, and by keeping system responses relatively simple. If possible, devices ought to be independent from each other. If devices are networked, the networks ought to be relatively small, and not linked to an overall home network. It is also important to think about power consumption. Recharging batteries is already a bother, and adding technology that needs electricity, but is not connected to electric network would add recharging exponentially. Perhaps even devices that produce their own electricity might be thought of – using solar energy, other light, or even kinetic energy [26].

What happens when we start to think proactive technology in terms of information systems, connected by either centralized or distributed intelligence instead of individual devices?

- *Design*. Even though we focused on ambient, non-critical elements, the task proved to be difficult. Even seemingly simple activities proved to be difficult to predict. Going to sleep is not a simple sequence that starts when someone observes that he is getting tired, and then makes a decision to go to sleep. This sequence involves probably hundreds of variations: someone starts the process by preparing tea, while someone brushes his teeth first. There are also many kinds of interruptions in the process: what about if the baby starts to cry? Finally, people reinterpret their aims, intentions and plans. For these reasons, proactive systems ought to consist of modules that function independently or as parts of a small network. A centralized system that tries to react to all kinds of activities that take place in parallel is overly ambitious.
- *Technology*. These problems translate into several technical problems. The placement of sensors is difficult, and they need to be replaced over time with changes in the home. Finding the right levels for sensors is another problem, and a third one is simply what to measure. Unlike bodily functions such as the heartbeat, it is difficult to reduce conversation into a graph. In conversation, action is in the specificity of what people say and how they respond to each other. Can evolving content in conversation be measured?

DISCUSSION

In this paper, we have studied proactive technology as "slow" technology [8] by combining a constructive and an interpretive research agenda. It is a promising idea that could solve many problems in existing smart homes. We tend to argue for adopting a "weak" version of proactive technology, if one brings it into the home. In our opinion, people ought to be kept minimally in the loop. They have to be able to direct technology. In our opinion, focusing on ambient things at home provides a way around the difficulties involved in trying to guess technologically human intentions or social activities from weak, measurable cues.

Our exploration of proactivity has combined a constructive and an interpretive field study through an iterative process in which field studies have led to more elaborate technology, and *vice versa*. Our study combined the efforts in electronics, industrial design, and the social sciences into an iterative research process. It built on the notion of "experience prototyping" [14], but with a twist: we wanted to take technology to real homes for long enough so that people would develop a routine for interacting with it. In our opinion, proactive designs must be tested in real homes, not in laboratories, in which people learn to use technology quickly, or in experimental smart homes in which people learn not just technology but also researchers' intentions. Only in real homes, designers get to see the full complexity of home history and meanings in objects.

Morphome became an exercise in interpretive design in contrast to the more typical research paradigm originating in usability. This study shows that the importance of sociological and anthropological studies of the home for design. If we think of the home metaphorically as a stage, we quickly realize that there may be tens of thousands of objects on this stage. We play many games on that stage too. Ultimately, only anthropological imagination can open the home for design in any degree of accuracy. We also need to understand embodied action at home better to improve our designs; however, by most studies of embodiment and related areas like tangible user interfaces have been conducted in laboratories, media art, and workplaces rather than homes [27]. No doubt, people leave measurable traces of their activities behind no matter what they do. The billion dollar question for technology development is which elements of action can be measured and interpreted reliably enough to be transformed into system responses that are meaningful for humans and ease their life.

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