# The Heterogeneous Home

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**ABSTRACT**
Due to several recent trends, the domestic environment has become more homogeneous and undifferentiated. Drawing on concepts from environmental psychology, we critique these trends. We propose heterogeneity as a new framework for domestic design, and we present design sketches that illustrate how ubiquitous computing technologies can interact with the domestic environment to create a more varied and restorative environment. This work speaks to a number of core issues in ubiquitous computing, such as how the increased presence of devices impacts quality of life, the desirability or undesirability of ubiquitous temporal and spatial availability of devices, and the advantages and disadvantages of device convergence ("all-in-one" devices) versus device proliferation (single application devices).

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## INTRODUCTION

A growing number of scholars have noted the increasing *homogeneity*, or uniform and undifferentiated nature, of the domestic environment. For example, the modern housing landscape has been critiqued as offering limited variation in internal form and structure [1, 28], and homes with uniform construction, ceiling heights, and lighting are symptomatic of designs that deal with economic constraints by being larger and undifferentiated, rather than smaller but more differentiated [24]. Additionally, fundamental domestic infrastructure, such as central heating and cooling systems that deliver a consistent climate throughout the home, reinforces the assumption that the domestic environment should be consistent and homogeneous.

Even in spatially complex homes, pervasive technology often provides access to the same "virtual environment" throughout the home, creating a homogeneous environment as viewed through the screen. "Anytime, anywhere" data access through cellular and smart phones can blur boundaries by allowing the same information to be accessed from anywhere in the home. Televisions playing in multiple rooms can also create similar landscapes throughout the home. Further, devices such as time-shifting television recorders can subtly homogenize the experience of time by reducing the salience of external temporal structures such as network television schedules [10]. Boundaries between work and home can also become blurred; laptops and PDAs connected wirelessly to the office may be placed on a bedside table, providing access to work late at night, and for many people the experience of truly "coming home from work" is a rare one.

Increased homogeneity in the domestic environment plainly offers attractions such as convenience. For example, uniform access to data and network services offers the ability to compute in locations throughout the home, from the kitchen table to the bed. However, this is a double-edged sword, resonating with concerns of McDonaldization, the process by which modern society takes on the characteristics of a fast-food restaurant [42]. While standardized and uniform services are convenient and seductive, they are also often associated with limited variation and reduced quality. These issues resonate with the authors' own intuitions, based on their experience with design and observation, that homogeneity is often associated with a less fulfilling domestic experience.

We have found it useful to consider these issues through the lens of *restorative environment theory* [34, 35], a framework used in environmental psychology to understand the relationship between mental fatigue and the environment. In this paper we describe restorative environment theory and use the theory to critique the increasing homogeneity of the domestic environment. In order to problematize homogeneity and suggest alternative viewpoints, we introduce the concept of the *heterogeneous home*, a domestic environment that provides choice about boundaries, connection, stimulation, and variation in the home. This discussion of the heterogeneous home explores key questions for ubiquitous computing, such as how the increased presence of computing devices interacts with quality of life, the desirability or undesirability of ubiquitous temporal and spatial availability of devices and services, and the advantages and disadvantages of device convergence ("all-in-one" devices) versus device proliferation (single application devices).

In the rest of this paper, we describe related work and our


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approach. We then elaborate on the concept of the heterogeneous home, presenting a series of design sketches exploring different dimensions of this framework.

## MOTIVATION AND RELATED WORK

The heterogeneous home is related to Weiser's [51] vision of pads, tabs, and boards: a diverse set of computing devices that integrate seamlessly into the environment. We present a new perspective on that vision that is informed by our observations about the use of space and technology in the home. Others have noted that the call for "seamless" technology frequently inferred from Weiser "is often opposed to the inherently fragmented nature of social and cultural encounters with spaces," arguing that "we need to be able to understand how pervasive computing might support rather than erase these distinctions" [17]. We agree with these arguments. Rather than designing technology to fade into the background of the home, we focus on the co-design of technology and the physical environment in order to create a rich domestic environment in which technology may be visually striking and highly noticeable, or unremarkable and unnoticeable, just like other architectural elements in the home. Like Harrison and Dourish [29], we argue that it is important to design to support the creation of *places* – "spaces" that are "invested with social meaning," and we highlight technologies that might help to create diverse places in the home.

Other domestic technologies resonate with the concept of the heterogeneous home. Elliot's Location-Dependent Information Appliances [20] are closely related, designed explicitly to fit into different information ecologies [12, 19] in the home. In a non-technological arena, Cranz [13] highlights the importance of physical motion and variation in seating position to well-being. Similarly, work highlighting the importance of physical motion when interacting with computing devices resonates with our argument for examining the physical form of technology. For example, Thimbleby found that people performed better using wide range of motion with a pen-based calculator on a large display than using standard push-button calculators [49].

Rather than presenting detailed descriptions of specific design proposals, our focus is to provide a framework for discussing and improving technology design for the home. Others have presented work in a similar spirit. For example, Gaver and Martin [25] used a workbook of inspirational design proposals to explore the design space of information appliances. Researchers have also used various combinations of literature analysis and design examples to create frameworks for understanding various aspects of technology design. For example, Gaver used artifacts such as the history tablecloth [27] and the video window [26] to illustrate the concept of *ludic design* for the home. Like us, he suggests that it is important to consider more than convenience and efficiency in the design of homes and domestic technology.

As part of our discussion, additional examples of specific technologies are referenced throughout the rest of the paper. First, however, we draw on related work in environmental psychology and architecture to argue for the importance of creating a heterogeneous domestic environment.

### Restorative Environment Theory

Restorative environments are environments that help reduce mental fatigue resulting from stressful situations or intense thought. Studies have shown that restorative environments have numerous advantages such as improved concentration, impulse control, and ability to delay gratification, as well as medical benefits such as improved recovery rates from surgery [48, 50]. Inspection of restorative environment theory suggests that the homogeneous indoor domestic environment is not sufficiently restorative.

Kaplan and Kaplan [34] frame environments in terms of their ability to either help or hinder people as they cope with the psychological costs of managing information. In particular, they frame restorative environments in terms of their ability to support the *understanding* and *exploration* of information. People have a desire to understand their environment, and a lack of understanding can result in stress. However, people also want to explore environments and uncover new information. A restorative environment successfully balances these competing needs; it is sufficiently *coherent* to promote understanding but sufficiently *complex* to promote exploration. For example, featureless expanses of open prairie are less restorative because they are too undifferentiated, while regions of dense vegetation are less restorative because they lack a clear focus. Other environments, like spread out trees near discernible trails (such as those often seen in English country paintings) are more restorative, promoting exploration while still offering a sense of order.

There are four hypothesized properties of the environment that make it likely to cause a restorative experience (from [34]): (1) *Being away*, or being physically or conceptually different from the everyday environment; (2) *Extent*, or having scope and coherence that allow one to remain engaged; (3) *Fascination*, or containing patterns that effortlessly hold one's attention; and (4) *Compatibility*, or fitting with one's purpose while in the environment.

While there are of course existing restorative uses of domestic technology, these factors highlight ways in which a homogeneous domestic environment can become problematic. For example, the ability to *get away* is limited by missing boundaries, such as reduced separation between work and home. These blurred boundaries, along with centripetal technologies like television screens or computers that rarely move, can collapse the effective *extent* of the domestic environment onto a few focal points within the home. Highly similar environments also lack the diversity of patterns crucial for supporting *fascination*. Further, homogeneous environments do not offer people different experiences depending on what they want to be doing, but rather offer similar experiences for all purposes, greatly limiting *compatibility*. The ability to achieve one's purpose can also be compromised by distractions, and multi-purpose computing devices often interrupt us [22] or enable us to easily follow tangents through data, creating a complex virtual environment with too many potential paths for exploration. Thus, some technologies in the home limit the ordered complexity of the physical environment, overshadowing it with a sometimes incoherent and distracting virtual environment. As Tabor

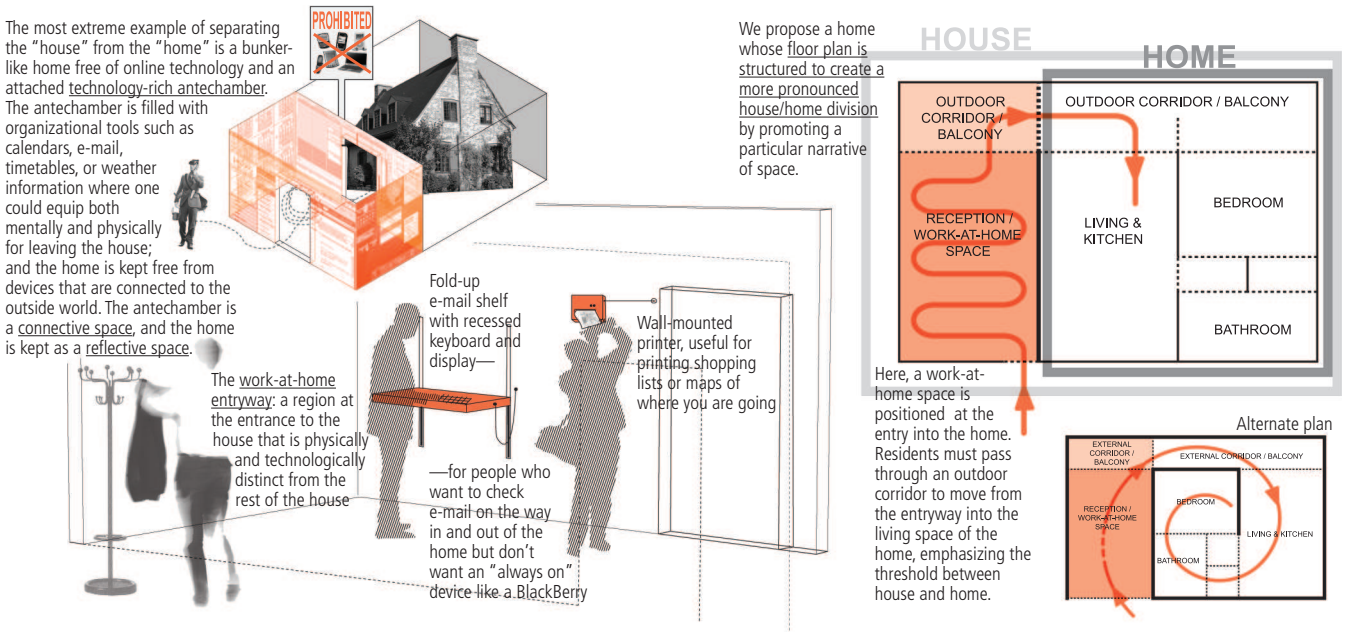


**Figure 1. Design sketches exploring house versus home**

writes [46], digital screens are "sleepless, fidgety, and demanding." They "discourage that mental state of still coherence – achieved when we stare into a flame, gaze idly from a window or watch shadows lengthen – which rebuilds the self."

## APPROACH

In this paper, we propose heterogeneity as a new framework for domestic design. Through this framework, we seek to articulate new design opportunities as well as to encourage critical reflection on existing trends and assumptions, and to question homogeneity (particularly as manifested technologically). The principles suggested by this framework are not necessarily incompatible with existing ones, but rather are additional resources for considering what constitutes good and effective domestic design.

In order to explore heterogeneity, we developed a design sketchbook [2]. The main function of the sketches is to demonstrate that our heterogeneous home framework offers a fertile design space for a wide variety of new objects and environments. The sketches are not necessarily literal design proposals. Some are more far-fetched and speculative, while others are more subtle adjustments to technology that already exists. To generate the design sketches, the authors engaged in a collaborative dialog with each other that drew on several resources and perspectives. These included concepts from environmental psychology and restorative environment theory; our experience conducting research in domestic settings (e.g. [52, 53], although note that the sketches are not based on specific user requirements or needs gathered during studies, nor have they been evaluated via user studies); our design experience with products and technologies, and our resulting intuitions and fascinations regarding how ubiquitous computing is employed; explorations with physical prototypes [3]; and a clustering and analysis of existing commercial products and research concepts and prototypes.

## DESIGNING FOR HETEROGENEITY

We now present several design proposals related to the heterogeneous home. These proposals explore ways in which ubiquitous computing technology and domestic space can be (jointly) designed to support a more heterogeneous and restorative home environment. In each section, we discuss opportunities for increasing domestic heterogeneity relating to the properties of restorative environments described above.

First, we discuss boundaries between living and working activities. We describe alternate technologies and spatial arrangements to better support work happening around the home, including housekeeping activities. We then present tourist objects, a form of technology that supports boundaries between domestic activities. Next, we discuss how technology can differentiate the temporal, physical, and social space of the home. We describe technologies that accentuate temporal rhythms, interact with outdoor spaces, and provide physical connections to virtual communities. Finally, we describe a fractal home that incorporates all of our proposals to create a diverse domestic environment.

### House versus Home

Laptops, the Internet, and cell phones make it possible to easily bring work home. These technologies can have positive implications such as allowing parents to work from home or reducing the negative impacts of commuting. However, this ability blurs the distinction between home and work and can make the home "just another place to work," breaking down the spatial and temporal distinctions between work and home. Others have noted the difficulty of establishing boundaries between work and home [23, 32]. In our studies, participants have spoken to us about the tendency of work to encroach on home life, describing how they check email late at night or spend too much time working from home. Gallagher [24] describes her efforts to keep home life from encroaching on work life, in particular by enforcing bound-

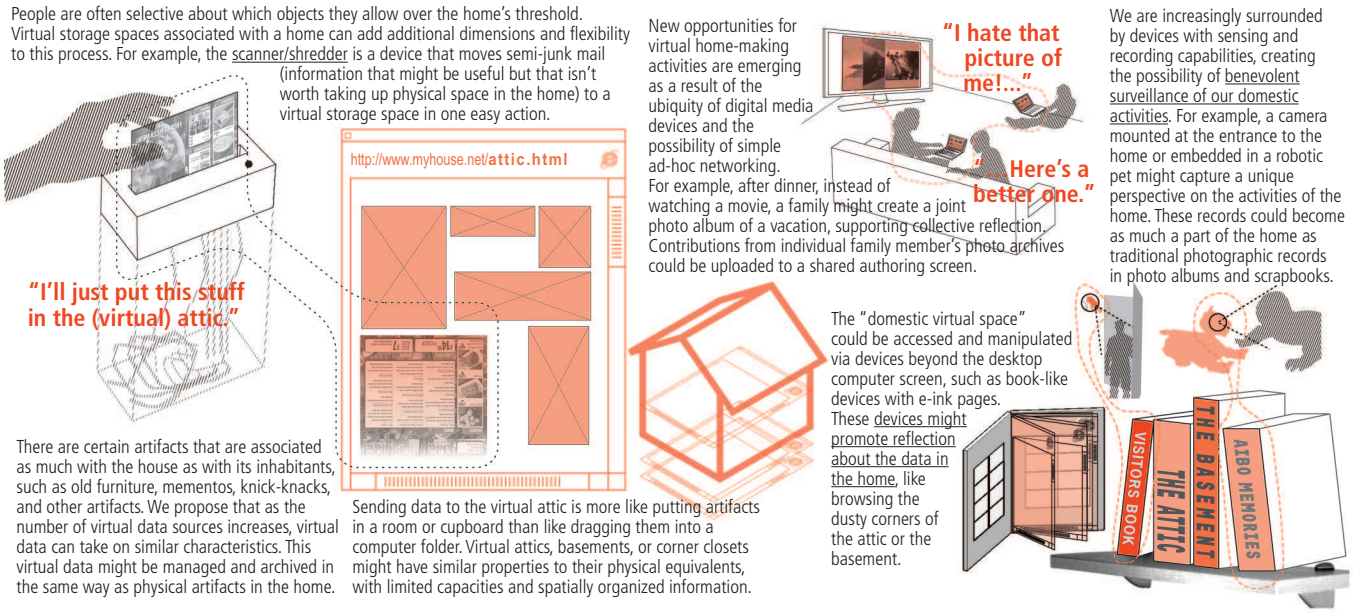


**Figure 2. Design sketches exploring hybrid homemaking**

aries between her home office and her children.

While work activities are moving into the physical space of the home, home life is also moving beyond the physical house – into cars or third places [39] like coffee shops. In some homes, for example in Tokyo, kitchens are becoming vestigial as nearby restaurants and take-out shops expand the home [45]. Atelier Hitoshi Abe proposes a home distributed across vacant rooms throughout a city that can be temporarily occupied [6], highlighting the idea of *home* outside of the physical *house*. The home is even moving into virtual spaces as people spend increasing amounts of time in online environments – online communities, networked video games, or virtual worlds like Second Life.

Exploring the gradations between *house* and *home* might help enhance heterogeneity, providing residents the opportunity to move smoothly between different environments like home and work while still affording boundaries between different parts of their lives. More differentiated environments would provide increased *compatibility* between the environment and tasks people want to accomplish. They could also increase the ability to *get away* by keeping home and work environments distinct.

As one scenario, we imagine a physical house that is bigger than the home inside. (We do not necessarily propose that people have larger houses overall, but rather that the allocation of limited existing space in domestic design might be reconsidered, e.g. in some parts of the world unused kitchen space might be more effectively allocated to another purpose.) For example, a house could contain a living space and a separate work-at-home entryway or parlor, creating a more pronounced, but still permeable, work/home boundary (see Figure 1). The ability to negotiate with technology at the boundary of the home was important to participants in our studies, and technologies such as networked printers or devices for checking email could be useful within an entryway. Other devices could help people manage technology as they returned home. For example, an inductive charging station could allow people to leave their laptop in its bag on the way into the home while still charging it to prepare for later use.

### Hybrid Homemaking

Examples such as the work-at-home entryway provide boundaries between working and living spaces. However, there are certain housekeeping activities, such as cleaning and cooking, that cannot be separated from the space of the home. We point out that these housework activities can be framed as *homemaking* activities – domestic work that involves making a "good home." Although there has been extensive discussion of problems such as division-of-labor in the home [11], the physical labor of housekeeping can sometimes be pleasurable, in part because it involves making the home a better place. Some have even lamented the introduction of "labor saving" domestic technologies because they can make housework less rewarding [54]. Other practices, such as preparing a meal as a family, can combine housekeeping activities with work that enriches the social experience of the home. Less productive housekeeping activities, such as pottering in a garden shed, can be restorative in their own right [55].

Key to the enjoyment of domestic work is the idea of *living processes* [4], actions that are intrinsically enjoyable, as opposed to those that are enjoyable only because of the end they achieve. Living processes can be enjoyable because they involve physical activity (e.g. gardening on a sunny day) or social interaction (e.g. sorting a music collection together). Kaplan suggests that the Zen emphasis on paying

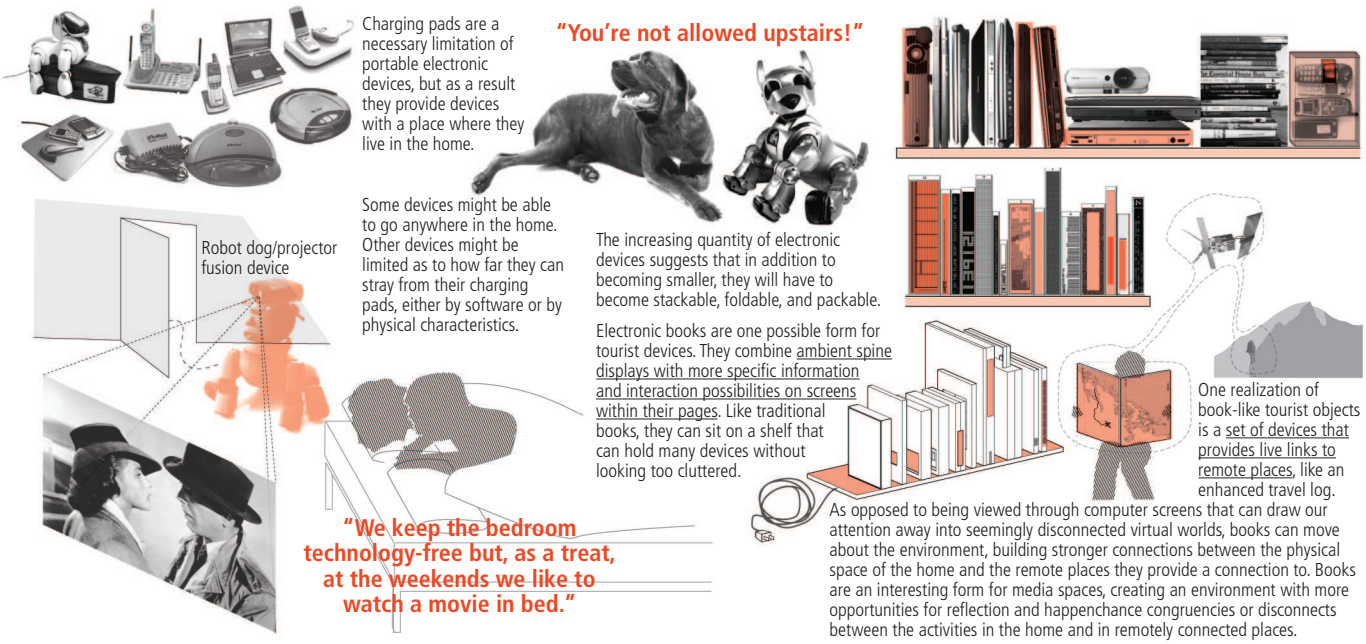


**Figure 3. Design sketches exploring device tourism**

attention to simple daily activities, like washing dishes or sweeping, can result in restorative effects [35]. Living processes create restorative experiences by providing more intrinsically *fascinating* activities that are enjoyable and thus *compatible* with the goal of having an interesting and rewarding life at home. We consider homemaking activities in the virtual home, exploring living processes for managing virtual domestic space.

Others have studied virtual homemaking activities, such as the archiving of digital personal data [36]. These archives often take physical form – we have observed participants who archived data by storing old laptops on shelves in their homes. Some design proposals consider physical devices for managing data in the home. For example, the Clutter Bowl [47] houses physical devices and the digital photos on them in a bowl that can "fill up" with pictures. Commercial products, such iPhoto books [5], help to create physical archives of virtual data. Other online services allow people to manage their virtual space in the same way they manage physical space, such as a Korean site that allows users to create a virtual "miniroom" that mirrors their own home [16].

We propose that it is important to support living processes of management and maintenance in the design of domestic technologies, incorporating the physical and social activities that can make traditional homemaking rewarding. In contrast to, for example, software that requires digital photos to be uploaded and labeled as soon as they come off of the camera, we consider different qualities of virtual storage and access that are more compatible with information ecologies [12, 19] in the home. As one example, we propose a scanner/shredder which sends artifacts that "might someday be useful," such as newsletters or articles, to a "virtual attic" (see Figure 2). Like the physical space of the home, this attic and other media spaces could be manifested with physical storage constraints, such as a limited number of e-ink pages in a book of the "house's memories." These physical constraints would allow retrieval based on physical location [30] rather than through search and (like a cluttered closet or attic) might encourage occasional spring cleaning and reflection. Opportunities to physically interact with the virtual home might allow us to be more reflective about and to discuss our electronic domestic artifacts as we manage them, making the process more enjoyable and meaningful.

### Device Tourism

As discussed above, the heterogeneous home is related to Weiser's [51] vision of pads, tabs, and boards. Weiser describes "invisible" technology that integrates seamlessly into the environment. This invisibility can create a more homogeneous environment by limiting the ability of people to create boundaries and to tune the extent and manner in which technology is integrated into their homes. Just as it is important to consider boundaries between work and home, it is also important to consider boundaries between technology-rich and technology-free spaces. These boundaries might support the ability to *get away* from technology when desired, or to surround oneself with technology that is *compatible* with a specific task. As one way of realizing these boundaries, we propose the idea of *tourist objects*, portable technological objects that support "seamless interaction but seamful technology" [40].

Tourist objects are single-purposed, portable electronic devices that take on heterogeneous forms such as books [3], robots, or portable PDA-like pads and tabs. The devices have "parking places" where they must occasionally return (e.g. to charge their batteries), creating a flow of devices around the home. They are similar to furniture whose use is flexible but that "lives" in a particular location. Like books and furniture, tourist objects can be rearranged, and tidied.

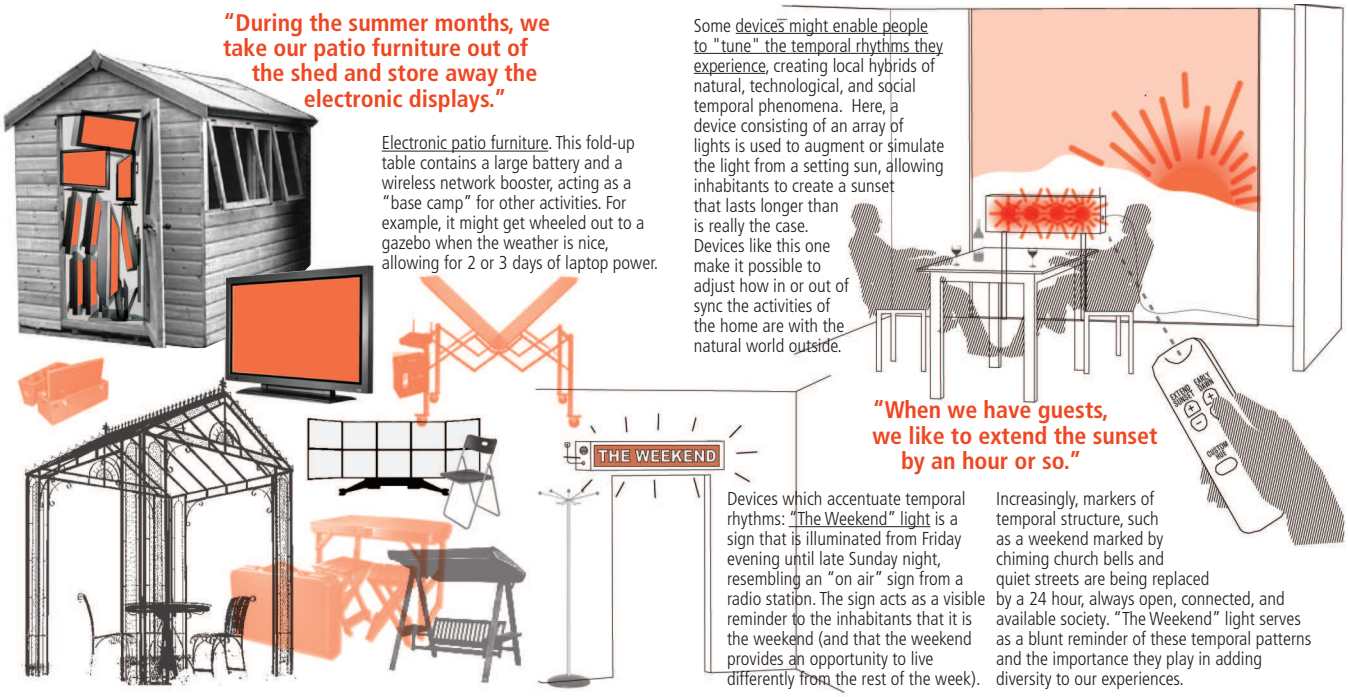


**Figure 4. Design sketches exploring the temporal home**

Because of their diverse and portable forms, tourist objects are able to move into more places in the home than, for example, laptops, which we have observed to be limited to a relatively small number of places within the home [53].

Tourist objects fit into an ecology of spaces with different levels of technology. For example, the technology-free bedroom (see Figure 3) reflects some of our study participants' desires to keep laptops and work out of their "personal havens," as well as resonating with long-standing advice from professionals such as sleep therapists. Such a bedroom would generally have very limited technology, perhaps only embedded in the door (see [6]). On special occasions, tourist objects such as a robotic pet with a movie projector or a book with an audio link to a far off location could "visit" the bedroom, providing opportunities for interaction with particular technologies when desired but a calm technology-free environment the rest of the time. Tourist objects might also interact with furniture in the home that is designed to support them.

Tourist objects might create a more heterogeneous spatial environment in the home without heavy-handed enforcement of the use of different types of technology in different parts of the house. Tourist objects are more heterogeneous than convergent devices such as Media Center PCs, but the fact that they have parking places within the home makes them less likely to contribute to an overly complex or cluttered environment.

### The Temporal Home

Temporal heterogeneity is important in providing structure to people's lives, for example through the changing of the seasons or through holidays during the year. However, there are a number of factors that limit temporal heterogeneity [38], including some factors in the home. Home infrastructure can diminish seasonal changes in space use. For example, central heating and air conditioning has enabled the entire space of the home to be climate controlled, resulting in diminished variations in space use during the year, such as the loss of the hearth as the center of the home during the winter. More recent changes such as mobile network technology have resulted in blurring temporal boundaries between time spent at work and time spent at home, supporting an increasingly prevalent culture of busyness [23], as opposed to exploring a range of temporal possibilities. Hochschild [32] argues that the home has become a site for work, always with too much to do.

Some architectural designs and domestic technologies do of course augment patterns in the home. Some designs emphasize natural patterns: three-season porches highlight seasonal changes, the Fog House [33] uses daily weather patterns to change the space of the home, and sustainable "green homes" designed to take advantage of sun and wind for heating, cooling, and collecting energy are more connected to temporal patterns of the environment. Other designs emphasize socio-cultural patterns. For example, many Jewish households use technology to help them observe the Sabbath as a day of rest, providing a completely different experience from the rest of the week [52]. These designs support differentiated temporal patterns that provide the ability to *get away* at different times during the day or week. They can also create increased *fascination* by revealing temporal patterns that might otherwise remain hidden or unnoticed.

We propose using technology to reify various temporal patterns, either enhancing existing natural patterns or bringing

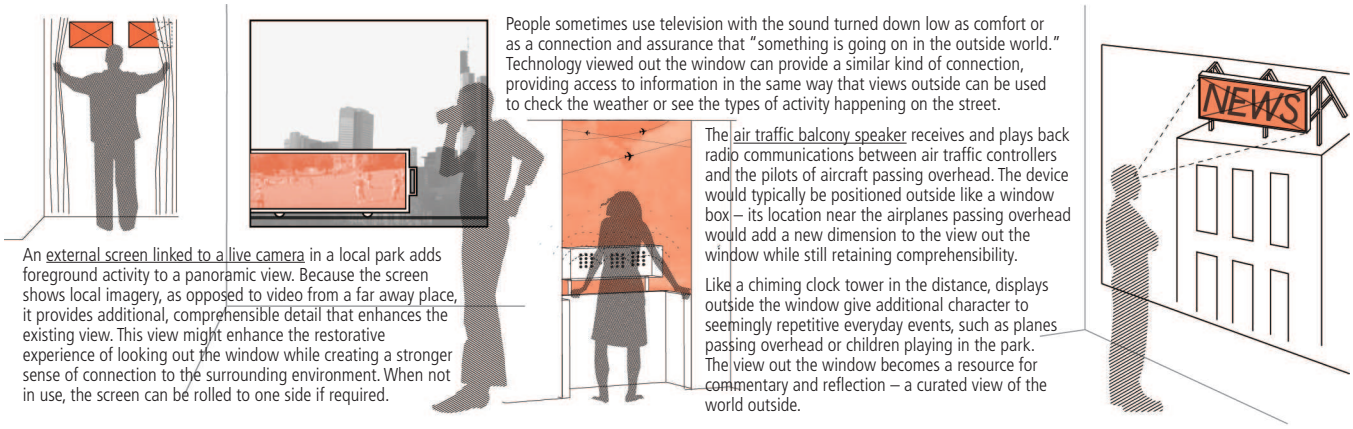


**Figure 5. Design sketches exploring the augmented outside**

new patterns into the home, in order to provide a temporal rhythm to life in the home (see Figure 4). For example, a sign above the door that lights up when it is "The Weekend" would introduce changes in the environment around a common pattern. Devices like a "sunset extender light" might promote awareness of temporal patterns by giving people the ability to shift them slightly on special occasions. And furniture designed to support temporal patterns might allow technology to better fit with, for example, the changing seasons – consider a laptop cart for use in a garden office during the summer.

Related to this concept of temporal patterns are technologies that capture the history of the home, helping to create a continuum between past and present within the home. For example, significant household artifacts like holiday dishes might have a memory of the events that happened when they were used in the past, such as discussions over family meals (see [27]). Other seasonal spaces, such as vacation homes or garden sheds, might record what happened while the owner was away between uses, providing alternate views of the space. These temporal rhythms would create a more heterogeneous environment and encourage reflection about the temporal patterns of life in the home. In addition to spatial complexity which creates restorative environments, we suggest that temporal complexity might also make the home a more restorative environment.

### Augmented Outside

Most literature on restorative environments focuses on natural settings, ranging from wilderness areas to small urban parks. Experiences in these settings are often highly restorative. Even watching the activity of the outside world through a window is a restorative experience [21]. However, interactions with digital domestic data occur primarily inside the home, as data are viewed through traditional screens such as PCs, televisions, and PDA displays. Even existing design proposals that create connections with the outside environment (e.g. [18, 26]) do so by bringing artifacts into the home. We suggest the home might become more restorative by placing technology and data outside of the home. This technology might provide the opportunity for increased experiences of *fascination* and *extent* by drawing attention to activities and patterns that exist outside of the home.

Artifacts outside the window and around the home could provide a venue for contemplatively "gazing out" at digital information or for allowing people to move outside and walk around a "digital garden." These artifacts could provide an alternate view on data collected within the home, or they could present data from the local community or beyond (see Figure 5). Such displays might encourage interaction with present but sometimes overlooked or invisible resources.

Objects in the augmented outside could also provide a means for connecting outward to the community by providing a venue for the data of the home to be "on stage" in the same way that gardens and artifacts displayed in the front window tell others about what is important to a household [28]. Finally, these objects might also explore interactions between technology and the natural outdoor environment, such as electronic gardens or park spaces that allow plants and animals to interact with outdoor technology [31].

### Physical Space for Virtual Communities

The relationship between the home and the community, especially the immediate physical community, is declining [41]. Modern households in America generally entertain less frequently in their homes, volunteer less outside their homes, and are involved in fewer activities, such as sports or other clubs. Activities increasing in prevalence are passive activities such as watching television, going to movies, and attending sporting events. Additionally, as communication technologies such as cellular phones and online communities have enabled the maintenance of connections with a distributed set of people, dependence on spatially proximate communities has decreased [9].

While we do not suggest that these distributed communities are any better or worse than more traditional local communities, we do suggest that the physical manifestation of community is important in establishing a heterogeneous domestic environment. Just as the use of metaphors of space and place in virtual communities has been successful [29], bringing those virtual communities into actual physical spaces may be similarly useful. Creating physical representations of virtual communities might increase the *extent* of the social community embodied in the home as well as providing increased *fascination* by highlighting patterns of interaction

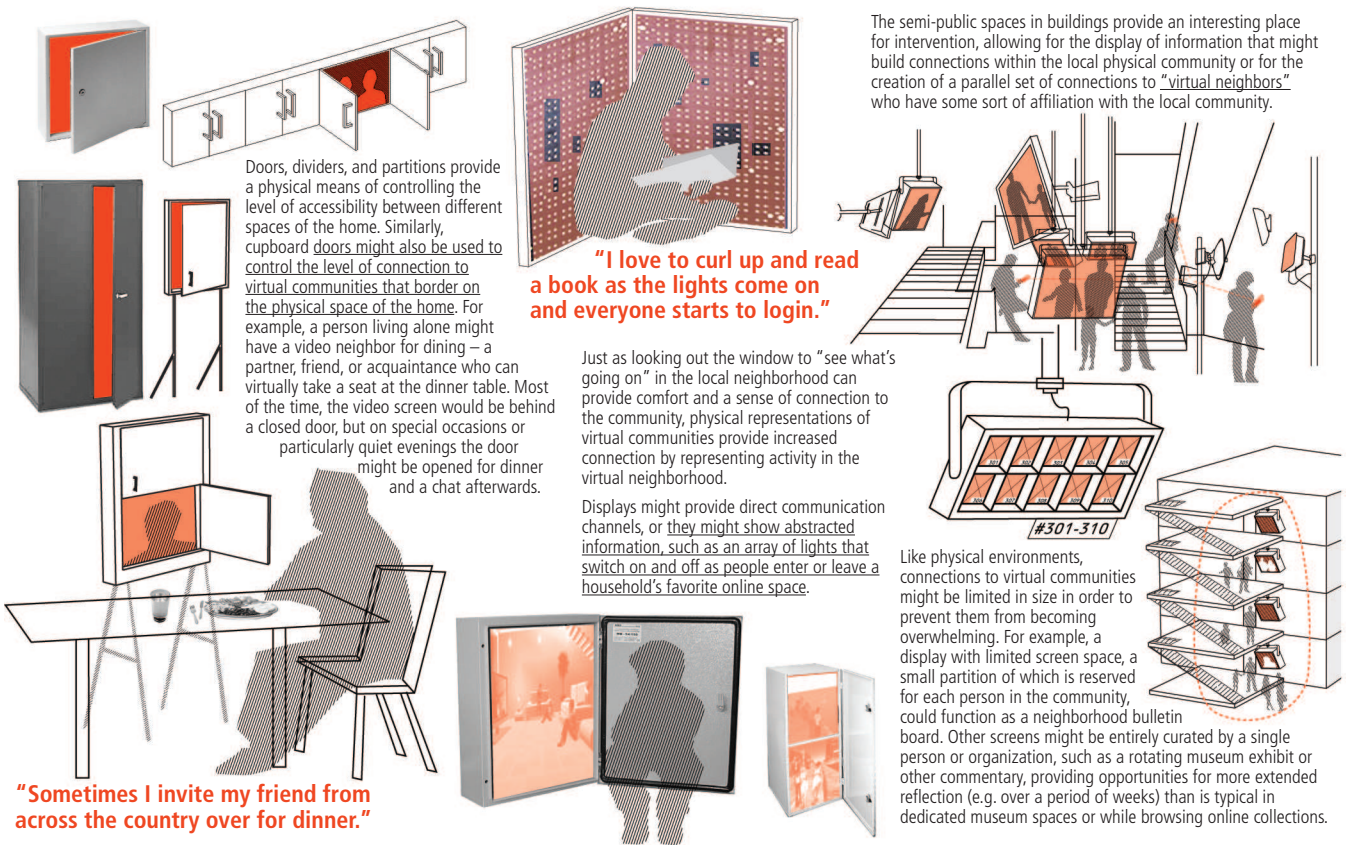


**Figure 6. Design sketches exploring physical space for virtual communities**

between other communities and daily life in the home.

The most important physical objects in many people's homes are reminders of friends and family (such as photos) or representations of their standing within the community (such as awards and plaques) [15]. As virtual communities composed of friends, family, and broader groups become increasingly prevalent and multi-faceted, we propose that these communities might similarly profit from a physical manifestation in the home. Network technology affords the possibility that, rather than being *representations* of community, technology in the home can create actual *connections* to these communities. For example, some existing technologies are designed to build connections within the household [43] or between pairs of people across different households [44], including between extended family members [7]. We propose similar connections to the broader community. For example, shared community screen-space within the home, such as a display with real estate alloted for each member of a community, could create a local community newspaper. Space such as an "in-home museum display" curated by members of the broader community might also build connections (see Figure 6).

Key to our proposal is the ability to control exposure to the community. The home is a private place, and one of its key roles is to provide sanctuary from the outside world. We do not suggest "always on" connections to community from within the home. Rather, our proposals focus on the ability to create varying levels of connection, such as the ability to "open the doors" onto a virtual community as the physical community surrounding the home quiets down at night.

### The Fractal Home

While a large, diverse physical environment, such as that in a sprawling estate home, might be heterogeneous and restorative, most homes do not have such extensive physical space. In exploring alternatives, we found Crompton's [14] concept of *fractal space* to be helpful. Fractal spaces are environments that appear bigger than they actually are because of the numerous opportunities they afford for variations in human occupancy. Examples include homes providing many hiding places for children playing hide-and-go-seek or museums filled with collections of different textures and shapes. Crompton's concept of fractal space is similar to our framing of heterogeneous space; like us, he highlights the fact that diversity of the spatial environment can create richer experiences.

Crompton's work inspired us to consider a home that has a range of spaces with different "fractal coefficients" [14] in different locations. For example, instead of being a *smart home*, the home might be a *semi-smart home*. Taylor *et al.*

[47] argue that intelligence in "smart" homes should come from inhabitants, not from specialized ubiquitous technology. We propose a middle ground in which parts of the home might be sensor-laden, intelligent, and proactive while others are relatively technology-free. Spatial complexity might also be varied to create a range of complex and differentiated places within the home, as shown in Table 1.

**Table 1. Dimensions of the heterogeneous home**

| Spatial Complexity | Virtual Complexity: Low | Virtual Complexity: High |
|---|---|---|
| Low | Zen garden, Technology free bedroom | Virtual reality "cave", 3D displays |
| High | Garden maze, Children's play room | Electronic foyer, places with many tourist objects |

Variation in technological and spatial complexity within the home acknowledges the relationship between the virtual and physical spaces we inhabit and gives residents choices about the amount and type of stimulation they receive from the virtual and physical world. This complexity with understandable choice is a key component of restorative environments, as was discussed in the introduction. Rather than containing one "right" space for every activity, the heterogeneous home enables people to create separate experiences by reconfiguring and exploring different aspects of the domestic environment. Bachelard [8] writes, "We have our cottage moments and our palace moments." We also have our working moments and our relaxing moments; our public moments and our intimate moments; and our active moments and our reflective moments. It is important to support clear differentiation of such experiences while also acknowledging the complexities of domestic life. The solutions we propose explore these issues, and suggest a diverse range of technologies and spaces that might make up the heterogeneous home.

## CONCLUSIONS AND FUTURE WORK

In this paper, we have presented a "heterogeneous home" view of ubiquitous computing, in which home environments and technological artifacts are designed to promote variation and differentiation of space and experience. We have described restorative environment theory and used the four properties of restorative environments (being away, extent, fascination, and compatibility) to critique the increasing homogeneity of the domestic environment. We have described a series of design proposals, each of which is concerned with creating a more heterogeneous domestic environment.

We hope that the ideas presented here will promote continued exploration of domestic technology, as well as consideration of restorative environment theory as a resource for critiquing and inspiring the design of technology. We note that in addition to serving as a partial inspiration for the ideas presented here, restorative environment theory also affords the possibility of being used as an evaluative framework for measuring the impact of technology on users' mental fatigue. A number of studies have considered how to measure the "restorativeness" of environments (e.g. [37]), and the adaptation of these measures to technology design is a promising direction for future work.


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