Data Souvenirs: Environmental psychology and reflective design

Ryan Aipperspach[a,*], Ben Hooker[b], Allison Woodruff[c]

[a]*GoodGuide, 98 Battery St. #400, San Francisco, CA 94111, USA*
[b]*Art Center College of Design, 1700 Lida St., Pasadena, CA 91103, USA*
[c]*Intel Research Berkeley, 2150 Shattuck Ave. #1300, Berkeley, CA 94704, USA*

Abstract

The physical form of technology and its relationship to the surrounding environment is an important factor in design; we argue that this is especially true in the design of reflective technology. We suggest environmental psychology theory as a tool for understanding this relationship and use it to propose design guidelines for tangible reflective technologies. As an example, we apply these guidelines to the design of domestic technology, inspiring the creation of *Data Souvenirs*, a set of hardware sketches we have built that combine technology with the physical form of books. Additionally, we reflect on our own design process, discussing how the combination of environmental psychology theory and hardware design sketches can motivate novel tangible designs.
© 2010 Elsevier Ltd. All rights reserved.

Keywords: Tangible interfaces; Design; Personal reflection; Environmental psychology

1. Introduction

In both the academic literature and in popular culture, the importance of personal reflection, or stepping back and thinking about one's life, is well established. Schön (1983) discusses how reflection can help professional practitioners be more effective, and numerous self-help books espouse the importance of reflecting on one's position in life spiritually, practically, and emotionally. Various technologies support these practices, including research prototypes (Gaver et al., 2007; Romero and Mateas, 2005; Morris, 2005) and commercial products for planning (such as Microsoft OneNote) or casual reflection (such as photo viewing and journaling software). However, some existing technologies can be counter-productive to the task of reflection. For example, devices like Blackberries and laptops provide an always-on connection to e-mail, work, and the Internet, potentially drawing one away from reflective activities. Additionally, while the multi-tasking nature of devices like laptops and desktops is often viewed as a positive attribute, they can also present distractions (Fogarty et al., 2005), limiting opportunities for extended reflection.

We are particularly interested in the relationship between reflection and the physical form of technology. In this paper, we highlight how work from environmental psychology, such as restorative environment theory (Kaplan and Kaplan, 1989), can help motivate new designs as interfaces become more tangible and closely connected to the physical environment. We suggest that these established theories are particularly useful tools in designing interfaces that fit into the evolving landscape of personal and domestic technologies, showing how new devices can help rather than hinder well-studied human behaviors such as personal reflection.

First, we introduce restorative environment theory and present design guidelines for reflective technology that are informed by restorative environment theory. As an example of their application, we use these guidelines to suggest the physical form books as reflective objects. We then describe the design and implementation of *Data Souvenirs*, one possible realization of this concept. Finally, we discuss how using Data Souvenirs as hardware sketches in

*Corresponding author.

E mail addresses: ryanaip@alumni.rice.edu (R. Aipperspach),
ben.hooker@gmail.com (B. Hooker), woodruff@acm.org (A. Woodruff).

combination with restorative environment theory helps to enrich the discussion of reflective technologies.

2. Related work

In considering reflective technologies, we chose to focus on the relationship between reflective technology and physical space. We present related work in each of these areas below.

2.1. Tangible reflective technology

The role of physical artifacts in helping to externalize identity and to aid in personal reflection has been studied by sociologists and anthropologists such as Csikszentmihalyi and Rochberg-Halton (1981) and McCracken (1991). These authors suggest that the artifacts in our environments help to define who we are; they are used to present our identity to others and to remind us of ideas or aspirations that are important to us. More specifically, a number of technologists have considered the role technological arti-facts and *reflective design* can provide in supporting reflec-tion (Norman, 2003; Sengers et al., 2005; Romero and Mateas, 2005). Sengers et al. (2005) define reflective design as "bringing unconscious aspects of experience to conscious awareness, ...making them available for conscious choice." While Sengers et al. consider reflection in the context of critical design theory, we have chosen to focus on technol-ogy to support the more everyday reflection of individuals reflecting on their daily lives, especially in the home. Specifically, we consider how the physical form of technol-ogy can provide appropriate support for this practice.

2.2. Existing reflective technologies

A number of designs have been proposed to support reflection through technology. We are interested in the relationship between technology and physical space in creating *reflective environments* (introduced in the next section). As a result, we have drawn inspiration primarily from technologies that interact with the physical environ-ment through the use of sensors to collect data and of embedded or tangible displays to reflect that data back to users.

Several technologies use sensor data to record, interpret, and present ambiguous reflections of activities of individuals and social groups such as households (e.g., Gaver et al., 2007; Romero and Mateas, 2005). These electronic data streams provide the opportunity to present data about people's lives back to them, defamiliarizing everyday patterns and opening them up for reflection. Romero and Mateas (2005) argue that these *alien presences* can "open unusual viewpoints onto everyday human activity, create pleasure, and provide opportunities for contemplation and wonder." Other tech-nologies focus on less ambiguous presentation of sensor data to allow more directed reflection about specific activities and memories. Examples include health feedback displays

(Morris, 2005), the Digital Photo Browser (Hoven and Eggen, 2008), and MyLifeBits (Gemmell et al., 2006). Additionally, more mainstream, existing technologies support reflective processes using desktop computing applications. For example, online blogs support journaling, and software such as Microsoft OneNote supports directed reflection in the context of task planning.

MyLifeBits (Gemmell et al., 2006) is an attempt to capture images, videos, documents, and other sensor data over the span of a person's entire life. The system has the potential to generate a large amount of data, providing opportunities for reflection about a life's worth of activities. In some instances, the scope of the data makes creating a coherent set of views relevant to a single reflective task difficult, and the creators acknowledge the need to augment search with the automatic generation of stories and paths through the data (Gemmell et al., 2006). Unlike MyLifeBits, the *Digital Photo Browser* (Hoven and Eggen, 2008) contains a more limited set of photos and uses physical *souvenirs* as tokens to help cue the display of contextually relevant data. In both projects, the ability to capture and comment on images and videos of important people and experiences creates a potential for creating rich and meaningful connections with one's life data.

The Tableaux Machine (Romero and Mateas, 2005) is an ambient display positioned in a prominent location in the home. The system uses sensors to record the types and extent of social activity happening in different regions of the home and then creates an abstract, collage-like repre-sentation of that activity. The goal of the system is to encourage reflection about the social activities in the home. Unlike PC-based systems, the Tableaux Machine consists of a dedicated display that better supports using the system in a more reflective location. The large display is in some senses like a window, providing a different perspective onto the activity of the home. Unlike MyLifeBits, the Tableaux Machine provides abstract interpretations of the activity in a home. This ambiguity provides opportunity for reflection.

The Home Health Horoscope (Gaver et al., 2007) is a system that uses wireless sensors in the home to monitor activity and create a customized horoscope related to the activities in the home. The horoscope is printed on ticker-paper once per day via a dedicated printer in the kitchen. Users reported anticipating the new horoscope each day, and the regular, daily updates created a unique reflective location in the space/time of the home. Like the Tableaux Machine, the horoscopes are intentionally ambiguous. Users reported being fascinated with the system and trying to decipher how it worked.

The Health Feedback Display (Morris, 2005) is a system that monitors the level of social contact an elder has with friends and family, which it displays on an in-home display. The display has an overview mode that shows changing interactions with a "constellation" of friends as well as a more detailed chart showing historical interactions with each individual friend. The display is targeted toward a very specific task, reflection about levels of social contact, and it

is very compatible with that task, providing multiple views on directly relevant data.

Our work is informed by and draws inspiration from the work described above. However, we focus specifically on the physical form of reflective technologies and how physical space and technology can interact to better support reflection. In considering this relationship, we draw on theories of physical place, as described below.

2.3. Reflective environments

A number of authors outside of the technology community consider the physical form that reflective objects and environments can take. Environmental psychologists Kaplan and Kaplan (1989) and others have explored *restorative environments*. Restorative environments are settings, frequently natural, outdoor settings, that help to reduce mental fatigue and stress. One of the benefits of restorative environments is their ability to support reflective activities (Herzog et al., 1997).

Restorative environments are environments that help reduce the mental fatigue that people acquire as they carry out their lives, allowing them to "get away" from hectic daily life and relax. Restorative environments have four common characteristics: *being away*, or providing a context "away from everyday life"; *extent*, or having enough room (real or perceived) to create a unique environment; *fascination*, or providing places or processes that capture one attention; and *compatibility*, or fitting in with the task someone is trying to accomplish (Kaplan and Kaplan, 1989).

Restorative environments can be characterized more specifically as *soft* and *hard* restorative environments (Herzog et al., 1997). Soft restorative environments are associated with quiet, natural settings, such as parks. Canonically, these environments are similar to English country paintings which include a trail, well-manicured fields, and several stands of trees, although they of course encompass a broader range of settings. Soft restorative environments provide extensive fractal details which help to effortlessly hold one's attention. Hard restorative environments similarly hold one's attention, but they often do so more directly. For example, watching an exciting sporting event or walking through a busy urban area may provide a hard restorative experience.

Kaplan and Kaplan (1989) list four benefits of restorative environments: (1) clearing the mind of unwanted thoughts, (2) restoring the ability for directed attention, or to be focused in thought and avoid distraction, (3) providing the opportunity to think about one's immediate problems, and (4) providing the opportunity for broader personal reflection. We are primarily concerned with the last two benefits. These benefits have been associated specifically with soft restorative environments (Herzog et al., 1997), and as a result we focus on that type of environment here. Specifically, we focus on designing technology that fits well into soft restorative environments and that augments their ability to support personal reflection.

In the rest of this paper, we expand on our discussion of restorative environment theory to suggest several design guidelines for reflective technologies. As a design exercise, we then use these guidelines to evaluate existing artifacts in the home, physical books, and use the guidelines to motivate the design of a new reflective technology, Data Souvenirs, which we describe in detail. Our goal is not to propose finished designs but rather to create design proposals (similar to, Gaver and Martin, 2000) highlighting how theory drawn from environmental psychology can be used to motivate the design of new domestic technology.

3. Guidelines for reflective technologies

In designing Data Souvenirs we drew inspiration from restorative environment theory. The attributes of restorative environments helped us to create several design guidelines for tangible reflective technologies. While we found these guidelines useful additions to our design process, we do not mean to suggest that they are the only possible guidelines for creating reflective technologies or that all reflective technologies should make use of our guidelines. Rather, we propose these guidelines as an example of how restorative environment theory can be applied to inform the design process. The guidelines are listed in Table 1 and described below.

I. Design portable devices. Restorative environment theory states that it is important to support *being away* from everyday experiences (Kaplan and Kaplan, 1989). Restorative environments provide the opportunity to get away, either physically (going somewhere else) or metaphorically (looking out the window or changing tasks), from the typical experiences of day-to-day life. Getting away makes it possible to take a more reflective stance about one's state in life by being slightly removed from it. Portable devices can be taken away from everyday locations associated with work or other activities, and even if they only move a few feet, e.g., from a computer to a table across the room, they give people the ability to get away from other less reflective tasks.

Additionally, Appleton's, 1975 theory of prospect and refuge suggests that people are more comfortable in locations that offer *prospect*, or a view over a diverse landscape, while still providing *refuge*, or a sense of protection from danger. The theory argues that early humans were drawn to

Table 1
Design guidelines for reflective technologies.

I.	Design portable devices that can be used in reflective locations.
II.	Create single or limited purpose devices.
III.	Provide multiple views on data relevant to a single reflective task.
IV.	Draw on intrinsically fascinating tangible interactions and changing displays.
V.	Provide information that is comprehensible enough to promote reflection while still encouraging interpretation.
VI.	Draw on forms that acquire meaning with age.

locations such as caves with views of a large landscape since they provided a strategic advantage in survival. While not necessary for the survival of modern humans, locations with prospect and refuge (such as a window seat with a view) are still appealing and well-suited to reflective activities. Locations providing refuge tend to be small and somewhat enclosed and thus do not necessarily accommodate traditional computing devices like desktop and laptop computers. This suggests that portable reflective devices must also take into account *micromobility* (Luff and Heath, 1998; Woodruff et al., 2007), or the ability to be used comfortably in a variety of configurations.

II. Create limited-purpose devices. One of the starting points in our design process was the fact that multi-tasking desktop computers are often distracting (Fogarty et al., 2005). In order to support *being away* and *compatibility* with reflective activities, reflective technologies must also make it possible to get away from the "information overload" associated with many computing devices. As a result, we suggest an ecology of limited-purpose reflective devices, each one providing information relevant to reflection about a particular activity or experience. Each device would allow users to get away and support extended interaction with reflective data. Alternately, some multi-purpose devices could better support being away if they were designed with several well-defined modes that made switching rapidly between multiple tasks intentionally more difficult.

III. Provide multiple views on relevant data. While reflective technologies should avoid providing too much information, they must also provide enough information to support users in a particular reflective activity. Restorative environments have *extent* allowing people to remain engaged, and people can become bored and thus easily distracted in environments that are not large enough to provide varied stimulation. However, these environments must also be sufficiently *coherent* to support directed exploration and prevent people from "getting lost" as they explore them (Kaplan and Kaplan, 1989). Thus, small or confusing environments provide limited opportunities for reflection. We suggest that reflective technologies should create extent by presenting data via multiple views with different levels of detail. This can create extent while avoiding the lack of coherence possible when presenting too wide a variety of information.

IV. Draw on intrinsically fascinating interactions. Restorative environments provide *fascination* and effortlessly hold one's attention. Environments can be fascinating as a result of content (i.e., containing interesting information) or of action (i.e., supporting an intrinsically interesting behavior) (Kaplan and Kaplan, 1989). For example, visiting a museum exhibit can be fascinating because of the information it presents, and staring into the patterns of a flickering campfire can be fascinating because of the patterns it contains. Fascinating environments hold one's attention, engaging the mind effortlessly and thus creating opportunities for uninterrupted reflection. Thimbleby (2006) argues that tangible interfaces, which engage *proprioception*,

the sense of physical motion, are inherently more fascinating and fun to use. We suggest that tangible interfaces, particularly when combined with provocative visual information displays, can support fascinating interactions and thus support restorative, reflective activities.

V. Provide comprehensible but provocative information. People often enter restorative environments with a particular task in mind, and environments must be *compatible* with that task (Kaplan and Kaplan, 1989). For example, in the context of reflection, individuals must be able to think about their immediate problems and to engage in broader reflection about their activities and goals (Herzog et al., 1997). Thus, reflective technologies must provide information that is actionable and can be understood in the context of problems people are addressing. However, providing a context that is too limited or concrete might limit *fascination*; reflective technologies must also provide information that is provocative, suggesting alternate views and interpretations as people engage in more open ended reflective activities.

VI. Support the development of meaningful artifacts. Objects that contain meaning and connection to the past provide hooks into self-identity or connections to important friends and family, providing context for reflective activities. Csikszentmihalyi and Rochberg-Halton (1981) found that important objects in people's homes often served as "role models", acquiring additional meaning as people reflected on them over time. For example, a grandparent's wedding ring is an important object, but its importance can increase significantly as it is used as an object of reflection and becomes associated with memories of one's grandparents after they pass away. People often listed these "contemplation objects", which included items such as art, collections, books, and photographs, as their most important possessions.

In a recent study of *mementos*, Petrelli et al. (2008) found that participants selected similar objects when asked to point out the special objects in their home. They also found that only one participant in their study included a digital object when asked to point out these special objects, highlighting the importance of tangible artifacts in building meaning.

McCracken (1991) points out that contemplation objects serve as tokens to help individuals externalize and strive toward attaining their ideal selves. And, Blevis (2007) argues that these heirloom objects can acquire additional meaning as they age. Thus, reflective technologies should strive to acquire meaning over time, supporting their development as contemplation objects. Pragmatically, this suggests that such objects must be durable and adaptable enough to age well and last over time.

Having presented these six design guidelines drawn from restorative environment theory, we now provide an example of their application. In the next section, we describe a design exercise in which we used our guidelines to motivate the design of a new domestic reflective technology that promotes the attributes described by restorative environment theory.

4. Designing new reflective technology

As we studied restorative environment theory and used it to develop our design guidelines, we wanted to explore how these guidelines could be applied in practice. As described by Vetting Wolf et al. (2006), design in HCI is a "wicked" problem that can often benefit from an iterative, creative design process. We set out to apply our design guidelines to building actual objects with the goal of learning from and improving on them.

At the beginning of our design exploration, we found that the physical form of books provided a good starting point for the design of reflective technologies. In this section, we describe how books meet the design guidelines presented above. We then describe *Data Souvenirs*, a series of hardware sketches that we built in order to explore this new design space.

4.1. Reflective books

In our design exploration, we discovered that books have affordances which support the design guidelines described previously. In this section, we highlight this connection through several examples. First, books are *portable (I)* devices that can be used in reflective locations. Unlike fixed-screen information devices, like computers or televisions that draw us into their screens (Tabor, 1998), books also afford the ability to adjust engagement levels. It is possible to be completely engrossed in a book and unaware of the surrounding environment, but it is also possible to take breaks from reading to look out the window or around the room. This makes the process of reading a book more compatible with requirements for prospect and refuge. The *micromobility* (Luff and Heath, 1998) of books makes them well-suited for use in reflective locations.

Books are also "at hand" but not in the way. This stems from the fact that books have a place to "live" – a bookshelf – which is an important factor in keeping them from cluttering the home. Bookshelves can accommodate a large number of books without seeming cluttered or taking over the environment. Similarly, books themselves can be present but tidied in the environment. When the environment is too messy, books can be arranged by neatly stacking them or putting them back on a shelf. These affordances of being tidyable and portable allow books to be at hand in many locations without creating an environment that is too chaotic. As a result, books support *ad hoc* interactions as people move about the environment, enabling reflection-in-action (Schön, 1983) in daily life. However, the fact that they are portable allows them to be taken to different locations, enabling people to get away when they desire.

Second, books are *single purpose (II)* devices. Unlike laptop computers, smartphones, and other multi-purpose computing devices that allow users to easily move between websites, tasks, or applications, books tend to have a single subject: providing in-depth information about a single topic or telling a single story. Additionally, interaction with books encourages extended periods of interaction with the same topic   once a book is chosen from the shelf or picked up from a table, some level of physical commitment is made to look at the content of the book. Further, books are less likely than computers to present distractions, in the form of interruptions (Fogarty et al., 2005) such as e-mail announcements or instant messages, or the easy accessibility of other applications. This focused interaction and content on a single subject also allows books to *provide multiple views (III)* on a single reflective activity.

Third, books are *tangible*. Thimbleby (2006) argues that interfaces which engage the sense of proprioception, or the sense that our physical actions are our own, can create more fascinating interactions. Along these lines, books are physical objects that support being moved around, flipping through their pages, and marking on them as they are read and explored. This physical interaction creates a more *fascinating experience (IV)* than interacting with a traditional computer screen.

Finally, books are capable of acquiring *meaning (V)*. The choice of books a person displays on a bookshelf is an effective way of presenting a particular self-image (Goffman, 1959). Additionally, Csikszentmihalyi and Rochberg-Halton (1981) and Petrelli et al. (2008) found that books were meaningful objects for many of the households they studied   they were the fourth most common contemplation object (after furniture, visual art, and photographs) (Csikszentmihalyi and Rochberg-Halton, 1981). The unique physical form of specific books gives them individual character as they evolve over time, gathering dog-ears, annotations, abandoned place-markers such as travel tickets, and other markings. We suggest that this character gives books a visceral quality encouraging repeated engagement and reflection on the relationship between the contents of the book and the state of the reader as both change over time. As one participant said in a study we conducted, when discussing the collection of memories in her daughter's scrapbook, "I want it different from a web site, where I want an actual book to open up" (Woodruff et al., 2007).

For these reasons, we have chosen to use the form of the book as a tool for exploring the creation of reflective technologies. Additionally, by taking advantage of an existing artifact that is already well integrated into the environment, books also allow for the integration of technology without requiring environments that are specifically built for smart applications. As Edwards and Grinter (2001) point out, "while new homes may be purpose-built for smart applications, ...it seems more likely that new technologies will be brought piecemeal into the home". In the next section, we present a more detailed description of *Data Souvenirs*, a specific realization of this concept.

5. Data Souvenirs

Data Souvenirs are electronic objects inspired by the form of books and the potential of sensor data to support reflective

activities, particularly around the home. In this section we discuss four examples that we built as hardware sketches to explore the design space shaped by restorative environment theory. We conclude by describing several other examples which we have designed but not implemented.

The physical construction of Data Souvenirs draws on the cardboard construction of many children's books that make use of a stack of laminated card pages surrounded by an additional cardboard cover. We chose this construction because it supports the integration of various types of electronic equipment, such as buttons, segment displays, or LCD screens through the use of pages of varying thicknesses. For example, buttons protruding from a page can be accommodated by thick padding pages with appropriately placed holes. Additionally, the construction of card books supports spines that are thick enough to contain electronic displays.

Each book consists of some type of display on the spine and one or more internal screens or buttons. Control circuitry is stored in a hollowed out set of pages at the back of the book. This control hardware includes a Gumstix computer and wireless network card attached to a custom board with power circuitry, LED light controllers, and connections to off-board components such as buttons and displays. This design enabled us to use the same primary board for each book, with a custom board containing only the display and interactive controls that vary across books. See Fig. 2 for a schematic diagram of a Data Souvenir.

In addition to constructing Data Souvenirs themselves, we also built a charging shelf, which provides several standard power pins that interface with sockets on the bottom edge of each book (see Fig. 1). Each Data Souvenir is connected wirelessly to a different source of data, supporting reflection about a particular domain. We present each in turn.

5.1. E-mail Management Souvenir (Fig. 3)

The first data souvenir, the E-Mail Management Souvenir, tracks the amount of time an individual spends using e-mail each day of the week in order to support awareness and reflection on the amount of time spent online. The device has a spreadsheet-like table of clock displays showing the amount of time spent on e-mail each
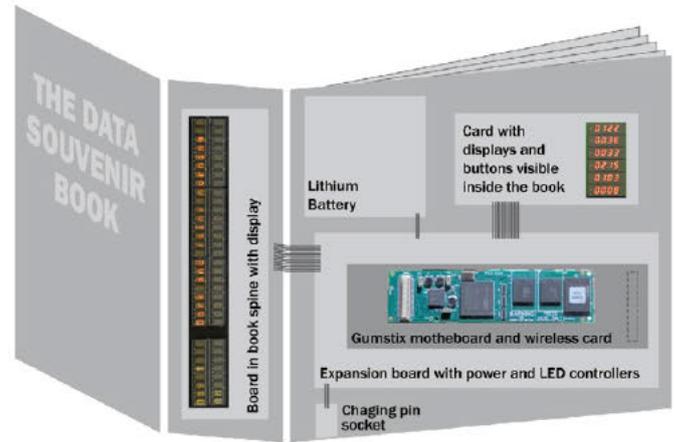

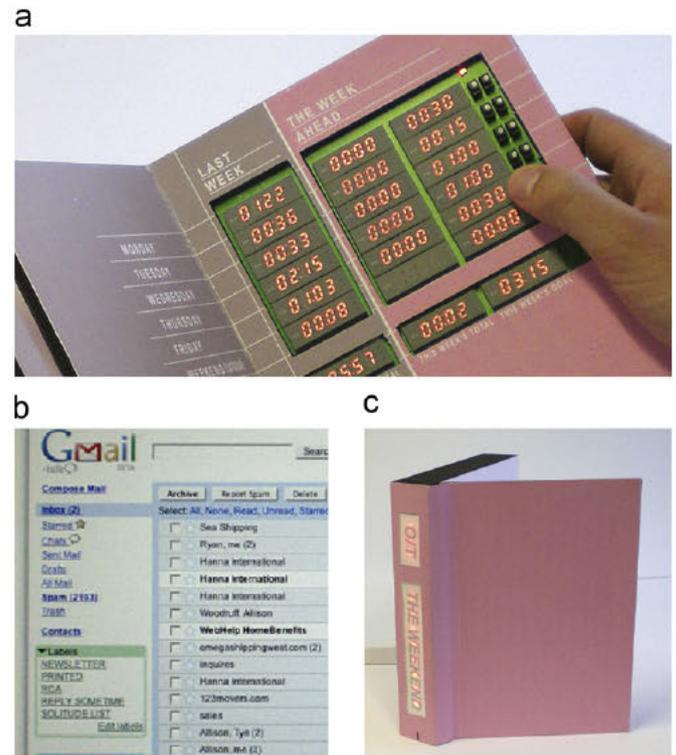
Fig. 2. Schematic diagram of a Data Souvenir.

Fig. 3. E Mail Management Data Souvenir. On the weekend, the spine lights up, highlighting "The Weekend" and allowing the user to review data from the previous week and to set a goal for the week ahead (a). During the week, the souvenir records how much time the user spends using e mail (b). If the user uses more e mail than set in her goal, the over time (O/T) light turns on (c).
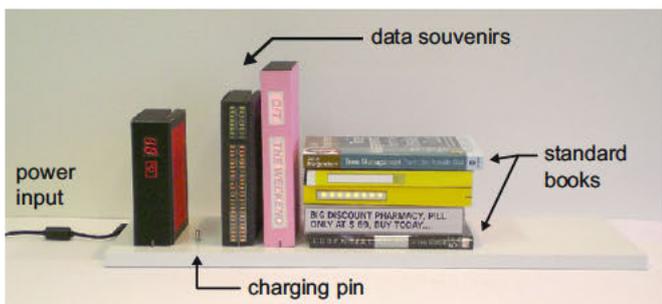

Fig. 1. Data Souvenirs on their charging shelf, along with other non electronic books.

day during the current week and the previous week. It also displays goals for e-mail usage for each day which can be adjusted using buttons on each row of the table. On the weekend, the spine lights up, saying, "The Weekend", drawing attention to the book when users might be in a more reflective state, planning the week ahead. The O/T (overtime) light on the device subtly notifies the user if her e-mail use exceeds her goal. This object, unlike a desktop utility designed to help "manage" e-mail use, intentionally encourages goal-setting and reflection away from the

context of an e-mail client with the goal of promoting more pensive reflection about one's e-mail use in general.

5.2. Webcam Photo Album (Fig. 4)

The Webcam Photo Album displays data collected from within and around the home but not related to computer activity. The album consists of a small LCD screen linked wirelessly to a portable webcam with a cellular modem. Users can position the webcam anywhere they would like. Every time the camera detects movement, a new image is uploaded to the souvenir, creating a visual history of a scene different from a traditional "edited" photo album. Buttons in the souvenir allow the user to cycle through the images on the device, and a separate "configuration page" (literally a different page in the book) has options for e-mailing images to the user's account, so that it can be saved or shared with others or deleting images. A numeric display on the spine of the object shows how many photos are currently in the album.

The album could be used to collect images from a variety of different sources. For example, the camera might be placed outside in the garden to capture images of wildlife as they pass by while residents are gone (similar to Dunne and Raby, 1994–1998), with the changing numbers on the spine notifying them of new images that arrived when they return home. The camera might also be placed by the front door to capture a history of everyone who passes through the home, or it might be placed in the living area of the home to capture an alternate perspective on the activities that happen there. These images might prompt household members to reflect, either collectively or individually, on the stream of people and activities that happen in their home, noticing different changes and patterns than those presented in a more edited photo album.

5.3. E-Mail Notification Souvenir (Fig. 5)

The simplest in structure of the Data Souvenirs, the E-Mail Notification Souvenir has LEDs on the spine that light up to inform the user whenever she receives a new e-mail message from a particular address, allowing her to keep tabs on messages from important people without having to frequently check e-mail on her computer. The e-mail address being monitored can be configured by connecting to a web server running on the Data Souvenir via the local wireless network. The Internet address of the souvenir is displayed on a screen inside the book. We imagine that users would have several notification souvenirs, perhaps of different colors, each connected to a different e-mail address or other type of data stream.

Unlike the other Data Souvenirs, the E-Mail Notification Souvenir is not designed to promote reflection about the data it presents (whether someone has recently received e-mail from a particular sender). Rather, it is designed to support the creation of a more gradated boundary between being online and off-line. In particular, the E-Mail Notification Souvenir (or other similar notification souvenirs)
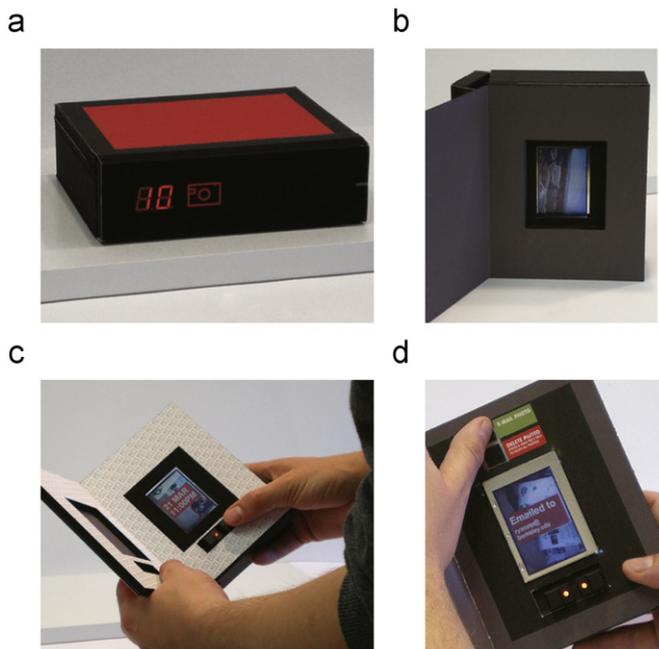

Fig. 4. Webcam Photo Album. The spine of the photo album displays the number of images, increasing whenever a new image arrives (a). The inside of the album can then be viewed through three different pages: the first page shows just the most recent image (b), the second exposes buttons allowing navigation between images (c), and the third contains controls for e mailing images to the user's account or for deleting unwanted images (d).
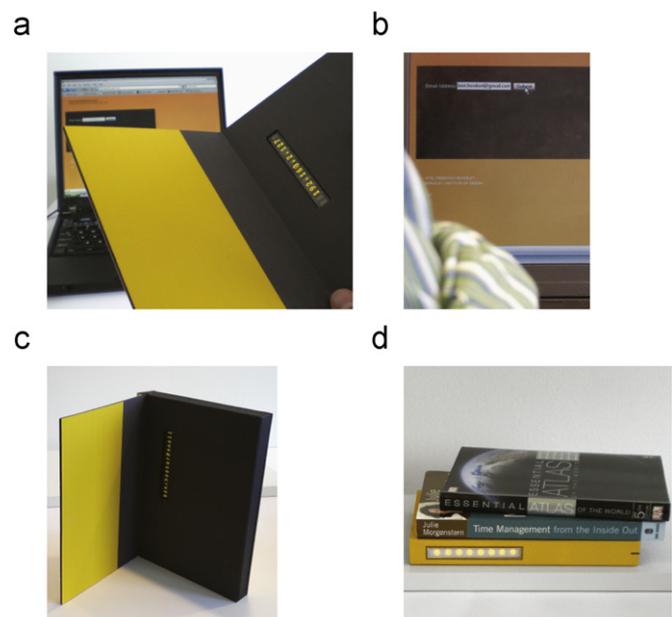

Fig. 5. E Mail Notification Data Souvenir. When first reset, the notifica tion souvenir displays its local Internet address on a display inside the book (a). Going to this web page allows the user to enter an e mail address to be monitored (b). This change updates the display to show the e mail address now being monitored (c). Then, when the user receives e mail from that address, the spine of the book lights up (d).

makes it possible to monitor online information, such as the status of an important e-mail, without being seated at a computer terminal. This provides users with space to engage in more slower paced, reflective activities without the need to frequently return to their computers to check the status of the virtual activities taking place there.
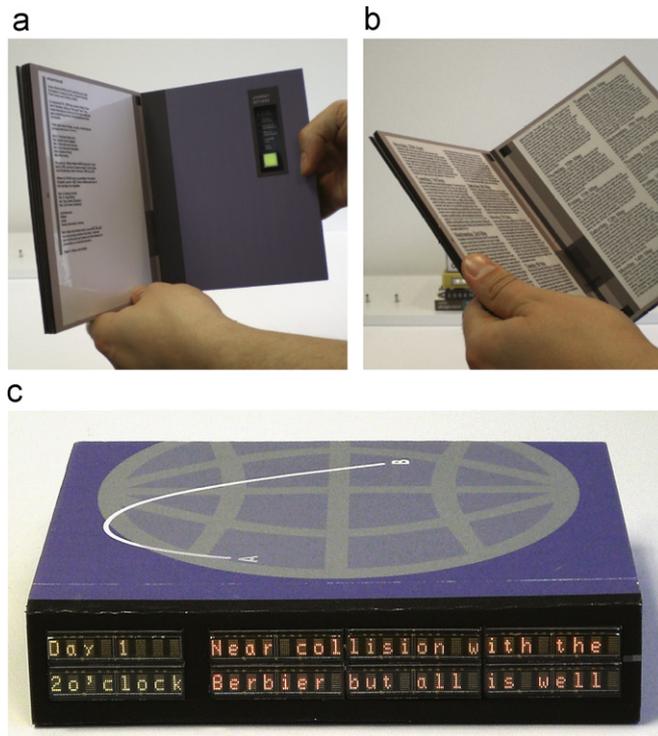

Fig. 6. Real Time Journey Souvenir. The user can select a journey to replay on the inside back cover of the book (a). Then, summaries of journal entries appear on the spine in real time (b). Whenever the user is interested in finding out more about a particular entry, she can open the book and read the full text on the inside (c). See Table 2 for sample text.

5.4. Real-Time Journey Souvenir (Fig. 6)

Unlike the first three souvenirs, the Real-Time Journey Souvenir presents data from outside the home. Specifically, the souvenir plays back pre-recorded journeys in real-time. For example, a voyage of immigrants sailing across the Atlantic would play back over the course of weeks and months, providing an alternative pacing contrasting with the fast pace-of-life in many modern households. This alternate timeline might encourage members of the household to reflect on the relationship between the lives progressing in their home with those playing out in the recorded journey.

During each journey, highlights of each new event are displayed on the spine of the book, and more detail (such as the full text of a diary entry) is printed inside the book. While our current implementation includes the full text of the diary on printed pages, it would also be possible to present the diary on electronic ink pages in order to reveal the text of the diary as the journey progresses. The pace of the updates to the spine might vary significantly. For example, during a sea voyage, the display might read "still at sea..." for weeks, followed by a flurry of activity after the ship lands. See Table 2 for an example of the entries and summaries displayed on the book's spine.

5.5. Other examples of Data Souvenirs

In addition to the prototypes described above, we have developed proposals for a number of other Data Souvenirs in order to explore the richness of the design space. Some of these examples are described below.

5.5.1. Audio/video connection to a remote location

One class of Data Souvenirs might serve as a reminder of and connection to locations that are important to

---

Table 2

Sample journal entries for Real Time Journey Souvenir. Journal entries were extracted from *Voyage of the Jane Boyd* (Ewing, 2005), the diary of Gordan Michie Ewing, an immigrant from Scotland to Quebec in 1855.

TEXT ON SPINE	CORRESPONDING JOURNAL ENTRY
Day 11, morning: Mate tells me we are 400 miles from departure pt.	We have had a fine night, but the wind not in the right part. The Mate tells me we are about 400 miles north west from Aberdeen. It is a beautiful day, the water calm, the weaves flat and broad. We have been sailing north and south this some days but the wind is now shifting. The ship is put about and we are now sailing slowly away to the west. The sun is shining, the people sitting in groups about the deck, and the children at their sport the same as if they were on the green grass. All are cheerful and happy and it is folly if the friends at Home should mourn for us. We want nothing but a drink of clear cold water. Our water is not very good. I have just been on deck seeing the sun set on the dark blue waters. A pigeon hawk came on board a little ago. The hawk was after the Chackert in a minute. We soon caught the bird and the hawk is sitting about where he best can. One sailor is playing on a flute, another beating on an old pan with two sticks. Caithness, Minty, Durno and I have long news' together often. Our only regret is that we have not our parents and friends along with us.
Day 11, morning: It is a beautiful day, the water calm	
Day 11, afternoon: Sport and music on deck	
Day 11, evening: Regret parents and friends not with us to enjoy day	

members of a household, such as sites of past vacations, former homes, or exotic locations. These links could be either audio or video links to remote sensors. For example, one Data Souvenir might contain speakers connected to a microphone near a beach house where someone once lived, allowing her to fall asleep to the sound of the ocean near her own home. Or, a video link to a webcam in someone's home town would let her check in on the activity on the main street. These souvenirs could serve as *threshold devices* (Gaver et al., 2008), providing an opportunity to reflect on data about the surrounding community.

5.5.2. Sensor data about life in the home

Other Data Souvenirs might collect and provide data about activities happening in the home. For example, an ecological footprint souvenir could track the energy use of or the amount of garbage recycled by a household, making it easier to become aware of consumption habits. Such a souvenir might be part of a pamphlet provided by the local utility company describing the services provided to the home. Additional souvenirs might collect more personal data for people in the home, for example by providing a reflective interface for viewing old text messages.

Data collected about the home need not be "profound", and Data Souvenirs provide the possibility of presenting mundane household data when it might be interesting instead of annoying. When placed in books on occasional tables or other lounge areas in the home, collections of spam e-mails, paper junk mail, or common keywords from Internet search engines might provide an interesting lens on patterns of changing activity and social trends.

5.5.3. Specialized "memento" Data Souvenirs

Some Data Souvenirs could serve as mementos of significant events, providing ongoing updates about activities people are interested in. For example, a souvenir might commemorate space voyages such as a "Mars Rover Souvenir" which could contain information about the space probes and their mission as well as a screen to provide updates as data are returned. The souvenir could be acquired at the beginning of a long mission, providing sporadic updates while the space probe was *en route* and then returning a stream of detailed data when the probe arrived at its destination.

6. Discussion

6.1. Designing Data Souvenirs

The Data Souvenirs we built were not intended to be final, working products. Rather, they served as a part of an exploratory design exercise in which we created sketches of our design ideas to promote discussion and critique. Here, our goals are similar to those of Gaver and Martin (2000), whose conceptual design proposals, a series of technologically plausible but still provocative proposals for information appliances, were created in order to "encourage broad

discussion" and inform future stages of design. This goal is similar to what Vetting Wolf et al. (2006) call a "design discourse agent ...a design artifact whose production creates a suggestive state that the designer in turn reacts to and is able to push forward. It is a tool for perpetuating alternatives, suggesting different ways of looking at something, and attempting to clarify a situation".

Our goal in designing Data Souvenirs was to explore the use of environmental psychology theory to shape the relationship between our designs and the physical environment. Specifically, we drew on restorative environment theory, which provided design inspiration based on the physical attributes of restorative spaces. This approach provided an alternative to task-driven design approaches. In following a design process drawing on both physical hardware sketching and on social-science theory, we found it useful to consider the metaphor of plot and character development in writing.

6.1.1. Plot-driven design versus character-based HCI: books as a "socio-cultural toolkit"

The author O'Connor (1979) suggested an alternative to plot-driven writing: "When you have a character he will create his own situation and his situation will suggest some kind of resolution as you get into it". For us, a consideration of the form of books and of the attributes of restorative environment theory helped us to develop the "character" of reflective technologies, which then inspired specific activities, or "plots" that could be supported by those technologies.

This relationship between plot and character can be viewed through the lens of Activity Theory (Leontiev, 1978). According to the theory, all of the activities that people carry out can be viewed as the interaction between *actors* (people), the *goals* they are trying to achieve, and the *tools* that they use to achieve their goals. Often, HCI research focuses on designing applications to support specific goals, as evidenced by evaluation methods that attempt to measure how efficiently an individual can complete a particular task. The resulting design activity, creating tools to support a specific activity's goals, embodies what we consider *plot*-driven design.

However, one could also imagine considering the affordances of tools and exploring the different types of activities they might support. Within the HCI design process, abstraction of the useful features of tools results in the creation of toolkits, such as Papier-Mâché (Klemmer et al., 2004), which provides support for developing tangible user interfaces. These toolkits provide affordances for supporting particular types of activities. While technical toolkits provide technological affordances for implementing new tools, we propose that existing non-technical artifacts (such as books) and the social-science theories that help us to understand them can suggest "socio-cultural affordances" for use in design.

For example, the Real-Time Journey Souvenir, with a dynamic text display on the spine and more detailed text inside of the book, was inspired by the form of existing

books as we asked ourselves how we could take advantage of the different levels of detail provided by books spines and interiors. Similarly, we were able to take advantage of culturally determined affordances of books, such as the fact that they "live" on bookshelves and are used to convey an individual's identity (Csikszentmihalyi and Rochberg-Halton, 1981), to enrich the experience of using Data Souvenirs. This design activity, in which tools can be used to suggest how the goals of an activity might evolve, embodies what we consider *character*-driven design. The process of designing and building Data Souvenirs helped us to uncover unique affordances of books, which we believe can be useful in motivating the design of other tangible interfaces. We describe several of these affordances below.

6.2. Affordances of Data Souvenir books

6.2.1. Data Souvenirs as ambient, tangible interfaces

The structure of Data Souvenirs places them in between purely ambient and purely tangible interfaces. As discussed above, books have the affordance of "living" on a bookshelf, where they are visible but in the background of the domestic environment. However, when they are taken off of the shelf they become a more central focus of attention. A shelf full of books can help to create a restorative environment because it is both coherent (showing only limited information about each book) and has *extent*, since each books hints at the range of information to be found inside (see Kaplan and Kaplan, 1989).

Data Souvenirs take advantage of this dual nature of books by placing displays both on the spine and inside of the book. For example, the Webcam Photo Album souvenir displays a counter on the spine showing how many pictures it contains. This display is an ambient monitor of the status of the webcam, and when the number increases, people nearby know that there is a new photo to look at. They can then take the book off of the shelf and open it, at which point it becomes a tangible interface for browsing photos. Similarly, the Real-Time Journey Souvenir displays excerpts from the current entry on the spine. These updates can be observed as an ambient display, but it is also possible to open the book for more in-depth information about the journey. In this way, the form of the book helps to bridge the boundary between the display of ambient information and interaction with that information without requiring real-time reconfiguration of the information display itself (see, e.g., Vogel and Balakrishnan, 2004). The relationship between inside and outside also provides possibilities for Data Souvenirs to provide data with differing levels of privacy. For example, the spine of the book might present public information while the pages inside could present information intended only for members of the household or for a single person.

6.2.2. Data Souvenirs in an information ecology

Reflective systems face a trade-off between providing extensive data via one system (such as MyLifeBits) and creating a specialized system with less data (such as Health Feedback Displays). Comprehensive systems have *extent*, but they may lack coherence, requiring users to navigate a large dataset. Alternately, specialized systems may present too little data, leaving users missing information that they would like to have while using the system. One possible resolution of this trade-off is to consider a hybrid solution that consists of an ecology of smaller systems, each providing detailed information about one aspect of users' lives.

Similar to Elliot et al. (2007), Data Souvenirs are designed to fit into the broader information ecology of the home (Elliot et al., 2005; Crabtree and Rodden, 2004). In particular, like books, Data Souvenirs can move between two types of information locations in the home: *ecological habitats* and *activity centers* (Crabtree and Rodden, 2004). Books tend to live in ecological habitats, such as on bookshelves or other types of horizontal surfaces around the home. However, books that are currently "in use" can also move to activity centers, and we imagine that during particularly important times (such as during an exciting part of the sea voyage being played back by the Real-Time Journey Souvenir) the books might be placed in these more prominent locations. Likewise, notification objects like the E-Mail Notification Souvenir can remain out-of-the-way on a bookshelf when not in use but be brought out when a particularly important e-mail is expected (as opposed to less "stowable" ambient displays like the Ambient Orb, 2010).

Data Souvenirs might integrate with other, more traditional information artifacts. For example, the charging shelf we built for the souvenirs (Fig. 1) is designed with extra space that does not contain charging pins, in order to support the inclusion of both Data Souvenirs and traditional books. Similarly, the ability of Data Souvenirs to be stacked and arranged, along with other books, magazines, and laptops, affords them the ability to integrate into locations within the domestic space without creating a substantially more cluttered environment.

6.2.3. Data streams and reflection

Similar to Gaver et al. (2007) and Romero and Mateas (2005), Data Souvenirs are designed to provide an *alien presence* in the home, exposing streams of collected data about which the household might reflect. Unlike these two examples, however, Data Souvenirs present less abstract data (such as photos, energy use statistics, or records of historical events) rather than abstract visual representations or horoscopes. Because we imagine people having a collection of Data Souvenirs suited to their personal identity, similar to collections of traditional books, people could choose the specific types of data they want to collect and interpret, providing opportunities for more directed critical reflection. For example, while the E-Mail Management Souvenir would likely not appeal to everyone, it would provide highly actionable feedback for someone interested in managing their level of e-mail use. The ability to comprehend the relationship between sensor readings and data representations resonates with the experiences of

Gaver et al. (2007), who found that participants' musings about what the Home Health Horoscope's sensors were doing often overshadowed their reflections on the actual activities taking place in their home.

The Data Souvenirs that we described above present streams of data from inside and outside the home. The data streams from inside the home, including e-mail monitoring and webcam photos, are designed to make the invisible visible, recording and playing back the activities of members of a household. These data streams promote direct reflection about the way users spend their time or arrange their homes. Alternately, data streams from outside the home, such as real-time journey playback, present different perspectives encouraging reflection about the activities of the home in relationship to other possibilities. For example, the sea voyage presented in our implementation of the Real-Time Journey Souvenir took several weeks to cross the Atlantic ocean, something that now happens in a matter of hours. This presents a different pace-of-life that contrasts with the "busyness" that characterizes many modern American homes (Hochschild, 1997). However, rather than presenting an editorialized commentary, the souvenir simply plays back the story of someone else's life in real-time, providing a parallel stream of data that might interact with modern user's lives in provocative ways. The object does not accept or reject conceptualizations of busyness. Rather, it provides a point of reflection to make people aware of the temporal rhythms of their lives. In addition to the sea voyage that we chose to comment on changing conceptions of time, other souvenirs might integrate modern stories from other cultures, modern day voyages of exploration (e.g., updates from a space mission), or news stories gathered from remote locations that are significant to a particular household. Each different stream of external data provides the opportunity to reflect on the relationship between daily life and issues outside the home.

We believe that book-like objects are well-suited for exploring patterns of change over time. As discussed above, books can be present in the environment without cluttering it. They can be read little-by-little over time, encouraging people to return to them, put them down, and pick them back up again. The interactive affordances of Data Souvenirs, particularly their ability to present changing data over time, augment this characteristic of books by allowing their owners to experience temporal patterns as they unfold.

7. Conclusion

In this paper, we have presented Data Souvenirs, book-like electronic objects designed to support personal reflection. We designed Data Souvenirs in order to explore how theories drawn from environmental psychology could help to motivate the creation of design guidelines for domestic reflective technology. We used these guidelines to highlight the affordances of books that make them well-suited to supporting reflection. In addition to discussing our design

outcomes, we have described a design process based on "character-based" inspiration and design sketches.

We found that our Data Souvenir sketches were much more helpful in conveying our ideas and promoting discussion than traditional paper-based sketches. Through creating Data Souvenirs as physical design sketches, we were able to share them with approximately one hundred fellow researchers and designers at open houses and demonstrations (e.g., Aipperspach et al., 2007). These interactions promoted interesting discussions and critiques, resulting in a number of open questions and suggesting directions for further design exploration.

For example, several people who visited our demo questioned the changing displays of the Data Souvenirs the appeal of traditional books is that they are permanent and long-lasting; however, the digital data presented by Data Souvenirs are continually changing. One possible implication of this comment is that electronic books should include a combination of digital displays and printed material, providing balance between their permanent and changing components.

Designing and discussing Data Souvenirs also raised several pragmatic questions about the construction of portable devices that feel like traditional physical artifacts. For example, our prototypes have several hours of battery life before they need to return to their charging shelf. This may limit the extended use of the books in alternate locations, such as on a bedside table. One possibility would be to use low-powered display technologies such as e-ink to increase efficiency. Representatives from a furniture company who visited our demo also suggested the possibility of creating an inductive charging system that would allow the souvenirs to be charged from any table or desk surface.

These open questions suggest possibilities for the future exploration of electronic books as a genre of reflective technologies. We are also interested in exploring the use of environmental psychology theories to develop character-based "socio-cultural toolkits". The specific guidelines for designing reflective technologies we presented here would benefit from being applied and tested in other design contexts. It also possible to apply theories from environmental psychology directly to other areas of HCI research. For example, researchers designing sustainable technologies may find it useful to draw on the form of existing, meaningful artifacts and "heirloom objects" (Blevis, 2007; Oehlberg et al., 2007) in designing technologies that are less likely to be used for a short time and then discarded as they age. The restorative environment theories we drew upon here constitute a rich body of work that could be used to inspire additional designs and to inform the critical analysis of a variety of reflective, tangible technologies.

References

Aipperspach, R., Hooker, B., Woodruff, A., Canny, J., 2007. Data souvenirs and reflection in the home. In: Adjunct Proceedings, Ubicomp '07.

Ambient Orb, 2010. Website, 〈http://www.ambientdevices.com/cat/orb/orborder.html〉.

Appleton, J., 1975. The Experience of Landscape. John Wiley Press, London.

Blevis, E., 2007. Sustainable interaction design: invention and disposal, renewal and reuse. In: Proceedings of CHI '07.

Crabtree, A., Rodden, T., 2004. Domestic routines and design for the home. Computer Supported Cooperative Work 13 (2), 191 220.

Csikszentmihalyi, M., Rochberg Halton, E., 1981. The Meaning of Things: Domestic Symbols and the Self. Cambridge University Press, Cambridge.

Dunne, A., Raby, F., 1994 1998. Weeds, aliens and other stories: cricket box. Website, 〈http://www.dunneandraby.co.uk〉.

Edwards, K., Grinter, R., 2001. At home with ubiquitous computing: seven challenges. In: Proceedings of Ubicomp 2001, pp. 256 272.

Elliot, K., Neustaedter, C., Greenberg, S., 2005. Time, ownership and awareness: the value of contextual locations in the home. In: Proceedings of Ubicomp 2005, pp. 251 268.

Elliot, K., Watson, M., Neustaedter, C., Greenberg, S., 2007. Location dependent information appliances for the home. In: Proceedings of Graphics Interface '07.

Ewing, G., 2005. Voyage of the jane boyd, 1855. Personal Journal. Online, 〈http://www.theshipslist.com/accounts/JaneBoyd.html〉.

Fogarty, J , Hudson, S., Atkeson, C.G., Avrahami, D., Forlizzi, J., Kiesler, S , Lee, J.C., Yan, J., 2005. Predicting human interruptibility with sensors. ACM Transactions on Computer Human Interaction 12 (1), 119 146.

Gaver, W., Boucher, A., Law, A., Pennington, S., Bowers, J., Beaver, J., Humble, J., Kerridge, T., Villar, N., Wilkie, A., 2008. Threshold devices: looking out from the home. In: Proceedings of CHI '08, pp. 1429 1438.

Gaver, W., Martin, H., 2000. Alternatives: exploring information appliances through conceptual design proposals. In: Proceedings of CHI 2000.

Gaver, W., Sengers, P., Kerridge, T., Kaye, J., Bowers, J., 2007. Enhancing ubiquitous computing with user interpretation: field testing the home health horoscope. In: Proceedings of CHI '07, pp. 537 546.

Gemmell, J., Bell, G., Lueder, R., 2006. Mylifebits: a personal database for everything. Communications of the ACM 49 (1), 88 95.

Goffman, E., 1959. The Presentation of Self in Everyday Life. Doubleday, New York.

Herzog, T., Black, A., Fountaine, K., Knotts, D., 1997. Reflection and attentional recover as distinctive benefits of restorative environments. Environmental Psychology 17 (2), 165 170.

Hochschild, A., 1997. The Time Bind: When Work Becomes Home and Home Becomes Work. Metropolitan/Holt, New York.

Hoven, E., Eggen, B., 2008. Informing augmented memory system design through autobiographical memory theory. Personal and Ubiquitous Computing 12 (6), 433 443.

Kaplan, R., Kaplan, S., 1989. The Experience of Nature: A Psychological Perspective. Cambridge University Press.

Klemmer, S., Li, J., Lin, J., Landay, J., 2004. Papier mâché: Toolkit support for tangible input. In: Proceedings of CHI '04.

Leontiev, A.N., 1978. Activity, Consciousness, and Personality. Prentice Hall, Englewood Cliffs, NJ.

Luff, P., Heath, C., 1998. Mobility in collaboration. In: Proceedings of CSCW.

McCracken, G., 1991. Culture and Consumption: New Approaches to the Symbolic Character of Consumer Goods and Activities. Indiana University Press, Bloomington.

Morris, M., 2005. Social networks as health feedback displays. IEEE Internet Computing 9 (5), 29 37.

Norman, D., 2003. Emotional Design. Basic Books, New York.

O'Connor, F., 1979. The Habit of Being: Letters of Flannery O'Connor. Noonday Press, New York.

Oehlberg, L., Aipperspach, R., Jeffery, S., 2007. Sustainability through meaning. In: Proceedings of the Workshop on Ubiquitous Sustain ability at Ubicomp '07.

Petrelli, D., Whittaker, S., Brockmeier, J., 2008. Autotopography: what can physical mementos tell us about digital memories? In: Proceedings of CHI '08.

Romero, M., Mateas, M., 2005. A preliminary investigation of alien presence. In: Proceedings of HCI '05.

Schon, D., 1983. The Reflective Practitioner: How Professionals Think in Action. Basic Books, New York.

Sengers, P., Boehner, K., David, S., Kaye, J., 2005. Reflective design. In: Proceedings of Critical Computing '05, pp. 49 58.

Tabor, P., 1998. Striking Home: The Telematic Assault on Identity. Routledge, London.

Thimbleby, H., 2006. Applying bohm's ideas in the age of intelligent environments. In: Proceedings of International Symposium on Intel ligent Environments, pp. 27 33.

Vetting Wolf, T., Rode, J.A., Sussman, J., Kellogg, W.A., 2006. Dispel ling design as the black art of chi. In: Proceedings of CHI'06, pp. 521 530.

Vogel, D., Balakrishnan, R., 2004. Interactive public ambient displays: transitioning from implicit to explicit, public to personal, interaction with multiple users. In: Proceedings of UIST '04, pp. 137 146.

Woodruff, A., Anderson, K., Mainwaring, S., Aipperspach, R., 2007. Portable, but not mobile: a study of wireless laptops in the home. In: Proceedings of Pervasive '07.