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PeerCare: Supporting Awareness of Rhythms and Routines for Better Aging in Place

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Abstract. Caring for the elderly is becoming a key challenge for society, given the shortage of trained personnel and the increased age of the population. Innovative approaches are needed to help the elderly remain at home longer and more safely, that is, to *age in place*. One popular strategy is to monitor the activity of the elderly: this focuses on obtaining information for caregivers rather than supporting the elderly directly. We propose an alternative, i.e. to enhance their inter-personal communication. We report the results of a user study with 14 independent elderly women and discuss the existing role that communication plays in maintaining their independence and well-being. We highlight the importance of peer support relationships, which we call PeerCare, and how awareness of each other's rhythms and routines helps them to stay in touch. We then describe the deployment of a technology probe, called *markerClock*, which a pair of elderly friends used to improve their awareness of each other's rhythms and routines. We conclude with a discussion of how such *communication appliances* enhance the awareness of rhythms and routines among elderly peers and can improve their quality of life and provide safer and more satisfying aging in place.

Key words: aging in place, awareness, computer-mediated communication, communication appliances, elderly, markerClock, PeerCare, rhythms, routines, technology probes

1. Introduction

As the population ages, existing support systems are being pushed to their limits and we require innovative solutions to meet the increased demand for care for the elderly. Many adults prefer to stay in their own homes rather than be cared for in an institution. Such *aging in place* allows them to remain in familiar surroundings, retain their independence, and not feel as though they are imposing a burden upon their children. From society's perspective, this is also less expensive and reduces demand on nursing homes and hospitals. Thus the question is: How can we help otherwise healthy, but somewhat fragile, elderly adults remain at home as long as possible, while maintaining both their safety and their quality of life?

Both researchers and institutions are exploring technological solutions that can support aging in place. One very popular approach is the use of moni-

toring technologies to ensure older adults' well-being (Sixsmith 2000; Mynatt et al. 2001; Rialle et al. 2001; Scharnberg 2006). The idea is to provide continuous monitoring of the person's behavior and to signal a remote caregiver if a problem is detected. Some problems require immediate intervention, such as a fall or a heart attack, whereas others identify unhealthy trends, such as decreased movement over a period of time. While sometimes necessary, monitoring poses ethical, technological, psychological, and social issues (Whitten et al. 1998; Sixsmith 2000). Many elderly reject the 'big brother' aspect and often refuse or forget to wear the associated monitoring devices. Devices may also fail, with potentially embarrassing or dangerous consequences. In addition, monitoring cannot be considered a complete solution for aging in place since it does not address psychological problems, such as loneliness or feelings of dependence, nor does it reduce social isolation induced by declining mobility and loss of friends of their own age (Donaldson and Watson 1996). Monitoring approaches focus on supporting the caregiver; the elderly benefit only indirectly and only in limited ways.

Our goal is to provide an alternative to monitoring that relies upon and enhances existing social behavior. Building upon established relationships among the elderly and their proximate social networks, we seek to support aging in place by providing computer-mediated communication (CMC). Specifically, we are interested in how Communication Appliances can promote independence for the elderly. We define Communication Appliances as: *"extremely simple, single-function devices that allow close friends and family members to stay in touch, by exchanging a variety of media (text, graphics, video, images, sound, etc.) over a continuously available link"* (Labrune and Mackay 2006). This paper describes our initial study of 14 independent elderly adults, which led to the identification of peer relationships as a key social element for ensuring safety while keeping loneliness at bay. We then explore how shared awareness of common rhythms and routines within a peer support group acts as the foundation for lightweight but effective communication about each other's state. We next describe the deployment of a technology probe (Hutchinson et al. 2003), based on a communication appliance called MarkerClock (Riche and Mackay 2007). Finally, we discuss how such devices can support PeerCare, in which the elderly stay in touch with each other, relying upon their shared understanding of each others' rhythms and routines to both maintain social connectivity and help each other in case of emergency.

2. Related work

This section describes various sociological studies that highlight aspects of aging in place, with an emphasis on those that might be supported by communication appliances. We then describe research relevant to the design of computer-mediated communication systems for the home.

2.1. The elderly and their social networks

A number of sociologists have studied the role of informal care of the elderly, particularly the importance of having friends nearby. Van Groenou (1995) argues that living in close proximity to both friends and neighbors is essential for well-being. Similarly, Cantor (1979) reports that neighbors and friends, especially those living nearby, are important sources of support for elders and have a positive impact on life expectancy (Giles et al. 2005). van Tilburg et al. (1995) emphasize the importance of social contacts both for care and social well-being and suggest that care giving within these networks involves two types of flow, with both material and emotional support. This notion of flow highlights the reciprocal nature of exchanges within the social networks of the elderly.

Despite their clear need for relationships, older adults are often isolated, especially after the death of a spouse or elderly friends. Moreover, since older adults typically have more difficulty establishing new relationships (Gierveld and Perlman 2006), their social networks can change dramatically when those close to them die or move away. Absence of close friends and informal caregivers who live nearby affects not only their physical well-being and safety but also their morale (van Tilburg et al. 1995).

We argue that interpersonal communication is an essential element for successful aging in place. In particular, we are interested in how computer-mediated communication systems can help the elderly to enjoy satisfying social relationships while maintaining their independence and safety. Like Tilburg et al., we emphasize the importance of reciprocity in social exchanges, rather than the uni-directional flow of information found in most monitoring approaches. To be maintained over time, these social exchanges must be viewed as lightweight, non-intrusive and enjoyable for both parties. Our goal is to help the elderly stay in touch with close friends, neighbors and caregivers as well as with more distant friends and family, to prevent feelings of isolation and strengthen their social networks.

2.2. Computer-mediated communication in the home

Computer-mediated communication has been a popular subject of research and design over the past two decades. Given its cost, early systems provided communication services for work settings, ranging from focused communication, such as video conferencing and video phones, to *media spaces* (Bly et al. 1993; Mackay 1999) which provide lightweight peripheral awareness among remote participants. More recently, researchers have been exploring a variety of communication systems for home settings. We studied these issues in the context of a 3-year participatory design project, *interLiving*, which developed a series of communication appliances (Hutchinson et al. 2003) that provide an informal and enjoyable means for inter-generational, multi-household families to stay in touch. For example, the videoProbe (Conversy et al. 2003) sets up a dedicated,

continuously active channel between two families. Each family has a screen equipped with a video camera, that automatically records a still image when it detects a lack of movement for three seconds. The result is a series of random (or posed) shots shared between the two households. The messageProbe uses the same dedicated channel between households to exchange hand-written notes with each other via a tablet screen. Markopoulos et al. (2004) developed ASTRA, an awareness system that lets family members outside of the home share pictures and handwritten notes with family members in the home. In field tests of all of these systems, family members experienced improved awareness of each other and an increased sense of interconnectivity. Although these studies provide valuable insights into the role communication plays in domestic life, they focus primarily on the family as a whole and do not explore the specific needs of the elderly.

Another active research area has been the use of computer-mediated communication to support remote relationships. Kaye et al. (2005) and Vetere et al. (2005) explored how minimal messages, such as a blinking light, can convey feelings of intimacy to a distant partner. They challenge Short et al. (1976) who advocate conveying the maximum of information possible to create a sense of shared *social presence*. Roussel et al.'s (2004) concept of multi-scale communication enables designers to move between the two extremes, promoting a variable level of engagement and reciprocity. Thus, what might otherwise be considered a poor communication medium may be suitable for exchanges requiring only low engagement between users.

MotionPresence (Bentley and Metcalf 2007) allows users to determine whether or not a remote friend or family member is currently mobile, based on the current position of their mobile phone. Couples who participated in the longitudinal deployment reported that such mobility information helped them to feel a greater connection with their partner. Similarly, Sellen et al. (2006) designed and evaluated an awareness device for the home called the Whereabouts Clock, which helped families become more aware of each others' location (Brown et al. 2007). These systems demonstrate how the exchange of minimal information, e.g., blinks and location, can provide effective awareness of each other's activities among people who know each other well. The key is their shared, existing knowledge of each other, which enriches their interpretation of even the most limited information and supports their shared awareness of each other.

Lottridge et al. (2009) identify the role of "empty moments" when designing technology to support remote couples. They found that couples who live apart are most likely to think of their partner when they are bored, engaged in mundane tasks or waiting for an event to begin. They developed MissU, a communication appliance in which partners a music playlist as well as ambient sounds, providing a multi-scale approach for sharing these empty moments. A key element of this and other communication appliances is the role of the dedicated, always connected channel: once connected, participants know that a particular device is always connected to a particular person, someone they know well. The actual

information exchanged, from extremely limited data, to richer messages and photos, to synchronous, live video connections, are all enhanced by the participants' existing knowledge and understanding of each other. Such dedicated communication channels help to balance the trade-off between detailed information and privacy, providing shared awareness and connectivity with minimal intrusion.

2.3. Communication appliances for aging in place

A few human-computer interaction researchers have explored the role of computer-mediated communication for the elderly. Forlizzi et al. (2001) and Morris et al. (2003) explore the role of social exchange among the elderly to encourage certain proactive behaviors. The Digital Family Portrait (Mynatt et al. 2001) displays images representing an elderly parents' activity around their portrait. Initially designed as a means to help adult children and their parents communicate, it later evolved into a one-way awareness device that monitors the parent's activity levels to improve the children's peace of mind (Rowan and Mynatt 2005). Metaxas et al. (2007) developed a monitoring device to support adult children's awareness of their elderly parent's activities. In these cases, the primary stakeholder is the caregiver, not the elderly person. Since remote caregivers lack information about what is currently happening with the elderly person, the bias is to create monitoring technology. While they address one important aspect of the social relationships between adult children and their elderly parents, i.e. wanting to know that everything is ok, they do not deal with the potential problems associated with monitoring technologies, particularly lack of privacy, but also lack of support for other forms of communication.

Internet communities, such as SeniorNet (Mynatt et al. 1999; Wright 2000), are an attempt to address the needs of the elderly for social networks. These technologies emphasize outreach, i.e. going beyond their traditional social networks to meet like-minded individuals. Most are based on online forums and emails and rely on a pre-existing level of computer literacy. They adapt existing technology, such as enhancing email to achieve greater accessibility (Dickinson et al. 2005). One potential problem is that such systems may be rejected by elderly users, if they feel that their deficits are being stigmatized (Forlizzi et al. 2001).

3. Initial user study

We conducted a study of elderly adults in France to investigate how they used various communication devices as well as their social networks within and outside family circles. We used Strauss and Corbin's (1998) approach for developing grounded theory in order to analyze our observations, interviews and artifacts.

3.1. Participants

We recruited 14 elderly participants, all living at home with various levels of independence. Note that recruiting proved more difficult than anticipated, in part because people do not appreciate being stigmatized as 'elderly' and because they did not see a direct benefit for themselves. We were more successful when we found individuals at clubs for the elderly who then convinced their friends to participate. Fourteen women, aged between 66 and 89 years, participated in this study. All lived independently, either in their own houses or apartments. Participants included one woman still living with her husband (who did not participate) and thirteen women living alone, either single or widowed. All were in reasonably good health and none required on-going medical care. However, each had some impairment or disability, caused by age, accident, or disease, that affected hearing, mobility, hand control, or eyesight. At the time of our study, seven participants were receiving support for home chores, e.g., house cleaning and ironing. Four women owned a computer, used for email and accounting. Only one had an Internet connection, a dial-up connection that allowed her to exchange email and digital photos with family and friends.

Eleven participants were recruited through two clubs for seniors in a southern suburb of Paris. We also recruited three women from a sheltered housing facility, one of whom introduced us to an elderly couple for two workshop activities. Note that participants who live in the sheltered housing do not receive formal care, but rather live independently in an environment designed for the needs of older people. As such, they are still aging in place, though they have moved away from their previous home and neighbors to live in an environment more adapted to their needs as they grow older.

This method of recruitment resulted in an over-representation of women. This is due to the greater number of female members in the clubs we solicited and the lower level of interest by men. Our results should thus be interpreted with care and may not generalize as well to elderly men, especially since there is already evidence that men and women handle relationships within social networks differently (Nussbaum and Pecchioni 2000). Since our goal is to lay a foundation for understanding how technology might improve aging in place, and since women make up a larger percentage of the elderly population, we believe that our results provide useful input to the design of such technology. However, it would be useful for future studies to explicitly study gender and cultural differences with respect to communication and aging in place.

3.2. Method

We combined field observation, interviews, cultural probes and workshops to gather qualitative information about elderly adults who live independently. Our goal was to understand their existing communication uses and needs and to identify the key aspects of their lives that affect their independence and well-being.

3.2.1. *Interviews and observations*

We began by interviewing the 14 female participants in their homes. The first part of the interview emphasized the gathering of recent and specific detail (Mackay 2002) about their daily lives, communication patterns, and interactions with other people and technology. We used a variation of a critical incident interview (Edvardsson and Roos 2001) to identify recent, memorable events. We also asked them to recall the previous day, in detail, and then asked them to tell what was 'typical' and what was unusual and why. We urged them to provide mundane details and also reinforced for them our interest in precise recollections over vague or general abstractions. We then conducted a semi-structured interview, focusing on their specific patterns of communication and their social networks, including family and friends. We explored interesting points raised during the first part of the interview and allowed them to discuss their communication needs and desires more broadly. We were particularly interested in the strategies these women had adopted to maintain their independence, especially those related to communication and social networks. Because we conducted the interviews in their homes, we were able to observe the location of their current communication devices and ask how they were used, both now and what they would like in the future. We recorded the interviews using either digital audio or video, as well as taking hand-written notes.

3.2.2. *Workshops*

The interviews provided individual perspectives about their communication within their social networks. To obtain a group perspective, we organized a series of workshops which enabled them to discuss and compare their experiences as well as provide us with an opportunity to discuss the results of our interviews. We selected a subset of participants based on their current group relationships, forming two groups of three people. Each group participated in two workshops, lasting one to two hours. These workshops enabled participants to discuss findings from the interviews and allowed us to create scenarios which stimulated discussion among participants and researchers. We were also able to discuss their technological preferences as well as their views regarding the integration of technologies in their homes and the types of media they felt were suitable for communication.

3.2.3. *Cultural probes*

Gaver et al. (1999) introduced the concept of *cultural probes*, artifacts that participants use to gather information about their own familiar environment. Originally intended as material to inspire designers, they have also been used to gather qualitative data in settings where other investigation methods, such as field observations, are inappropriate (Crabtree et al. 2003). Hutchinson et al. (2003) describe how these two goals can be combined, providing both specific data about current activity and inspiration for designing novel technology.

We created five packs of communication probes, modeled after those used in the interLiving project (Beaudouin-Lafon et al. 2001), which included a disposable camera and a set of postcards (See Figure 1). The postcards asked participants to answer a specific question, with an illustration designed to provoke them to 'fill in the gaps'. We also printed instructions on the camera, asking them to show us different examples of objects, e.g. something beautiful or something practical.

Inspired by interLiving's relationship map (Mackay 2004) and Forlizzi's et al. (2001) social network map for the ELDer project, we created a third probe that asked participants to map their social network onto a set of concentric circles.

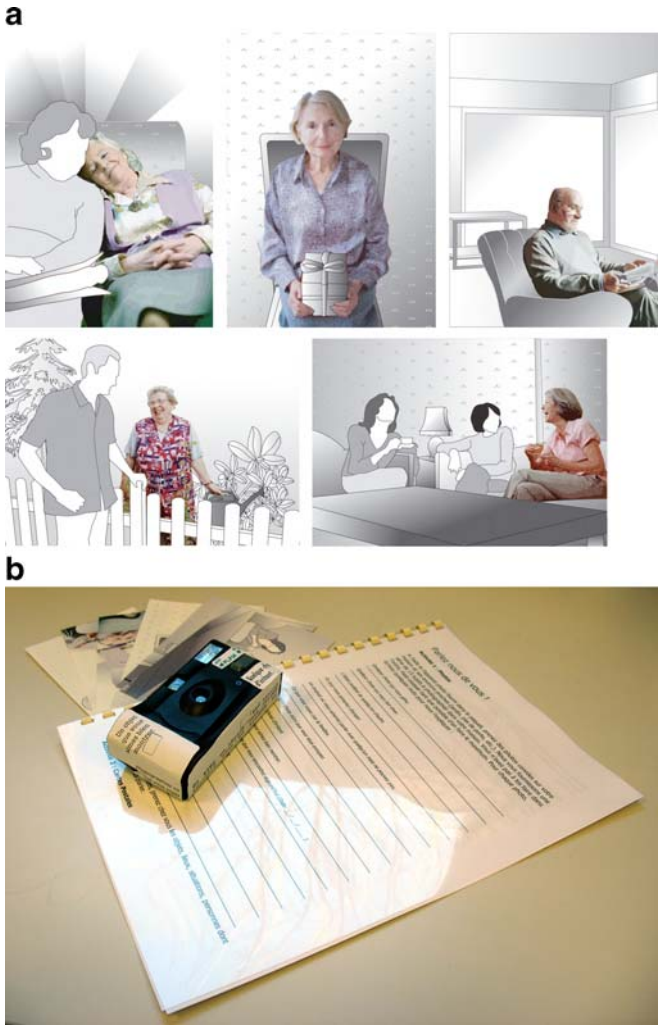

Figure 1. The probes kit used in the study. The images on the left are the illustrations for the postcards.

They placed labels of their friends, relatives, neighbors and other people of importance according to frequency of interaction, with most frequent in the innermost ring. We asked them to fill in details about each person, including their relationship and encouraged them to think about their relationships with respect to temporal, geographical and emotional importance. We explained the tasks associated with each kit and included a booklet where they were encouraged to comment on their photos or provide us with feedback, either about the probes or the study in general.

3.3. Data analysis

Throughout this study, we collected a variety of data including notes from the interviews, cultural probe results and over twenty hours of video and audio recordings from the interviews and workshops. We based our analysis on Strauss and Corbin's (1998) grounded theory. In particular, we used microanalysis for looking at our initial data, examining it closely (many times over) and generating initial codes based on this analysis. Rather than using a given taxonomy for these codes, we extracted salient recurrent themes and created our own set of codes. We then used these codes to analyze the remaining data, adding new codes when necessary. Cross examination of these codes helped us to group them into categories and contrast them with each other. The codes created by one researcher were then validated through discussion with the other researcher and participants in the study, which helped us to correct several misinterpretations and identify new directions to explore. These results are, of course, subject to our biases and should not be considered either exhaustive or conclusive. However, our use of multiple data gathering techniques, including observation, interviews, cultural probes and workshops, provides an effective form of triangulation (Mackay and Fayard 1997) and our results serve as an important foundation for informing our subsequent design of communication technology to support seniors.

4. Results

We have organized our results into three primary categories: *PeerCare*, the peer-to-peer support behavior we observed among our elderly participants, based on both social relationships and specific care behaviors; *Awareness, rhythms and routines*, which explores the role of rhythms and routines in helping people remain aware of each other; and *PeerCare and privacy*, which discusses the trade-offs between privacy and peer support.

4.1. PeerCare

Several participants reported an interesting strategy for helping to them feel safe and socially connected. They created a local group consisting of a few neighbors,

elderly widows like themselves, who 'keep eye on each other'. It is important to note that their care for each other is reciprocal, rather than a care giver/ care recipient relationship. Their relationship is also social: although they are not necessarily best friends, they know they can rely on each other in time of need. Finally, they are peers; each lives alone yet values social contact, each wants privacy and independence, but recognizes her own vulnerability, and each wants to be needed while also needing others if there is an emergency. We call this form of reciprocal support relationship *PeerCare*.

4.1.1. *PeerCare: social and care exchanges*

The story of a woman we'll call Beatrice offers a number of insights into PeerCare relationships. Beatrice has no children but regularly exchanges phone calls and visits with her siblings and their children. When her husband died 2 years ago, she moved into town to be closer to facilities like supermarkets and doctors. Although her smaller apartment is practical, it also means that she is further from her old friends. When we asked her who she would turn to in an emergency, she did not mention her family or her close friends, but rather three of her neighbors, Gertrude, Helen, and Nicole, with whom she interacts regularly. All recent widows, they have established a set of daily habits that enable them to socialize and care for each other. The laughingly refer to themselves the *Gang of Four* and rely upon each other in multiple ways.

One central element of PeerCare is *social exchange*. The *Gang of Four* established and maintained a strong social relationship through regular visits and shared activities, allowing them to avoid loneliness. Beatrice and Helen live next door to each other in the same apartment building, while Nicole and Gertrude live in the adjacent building. Every morning, at least one of them goes to the intercom at the front door and chats with each of the others. They only spend a few minutes exchanging news, but it is an easy and opportunistic form of communication and is cheaper than a phone call. These quick intercom chats often result in shared activities, such as shopping, a game, a walk in the nearby park, or, on weekends, an afternoon tea. These frequent, informal exchanges allow everyone in the group to remain aware of each others' whereabouts and general state. These social exchanges contribute to each others' well-being but are not explicitly about caring for each other.

The second central element of PeerCare is *care exchange*. The *Gang of Four* explicitly rely upon each other to detect and react to emergencies. For example, they exchanged keys so that any member of the group can enter the apartment of any other member, if they suspect something is wrong. They also exchanged emergency contact information, to ensure that doctors and family members can be informed. In addition, the group functions as a support group if one of the members is in need. For example, when Beatrice was recovering from a stroke, Helen, Gertrude and Nicole took turns helping her in the morning and at night to prepare meals and maintain her home. These care exchanges can be part of

the group dynamic, as illustrated earlier, or emerge between individuals in the group. For instance, every morning since the stroke, Beatrice signals Helen by calling her and letting the phone ring three times to indicate that she is awake and safe. The morning of our interview, Helen called Beatrice to check on her because she had *"not heard the phone ring"* and thus called to make sure Beatrice was OK. Although these exchanges have social elements, they are primarily about caring for each other. It is also important to note that the members of the Gang of Four are very protective of their dignity; there is no stigma attached to answering or not answering the phone and everyone feels both needed and cared for.

4.1.2. *Intrusiveness, family and PeerCare*

Family members, especially those who live in close proximity, play an important role in supporting aging in place. Depending on their level of independence, participants had different views of who provided support for whom. Some viewed themselves as caregivers who provide support for their grown children, such as when they babysat their grandchildren. These participants were wary of intruding on their childrens' privacy, e.g., when Irène said she tries "*not to interfere because I know they are very busy. […] I put their privacy first. […] I interfere as little as possible. If they have a problem, they know I am here*". Other participants viewed themselves as recipients of their children's support, such as when Gertrude relies on her son to do her paperwork or perform minor manual jobs. Still others viewed themselves as both care givers and care recipients. Thus Françoise considers her sons to be her main source of support since her husband passed away but also emphasizes that she does not want to be a burden to them.

Participants often characterized their relationships with their families in terms of who initiated the communication, e.g., *"I am usually the one calling"*. Many felt that the situation was not reciprocal and felt either irritated by it: *"Today the younger people would rather send an SMS or give a phone call, but it is not the same"*, or worried about invading their children's privacy and ended up visiting less often or contacting them less often than they would like. Most participants were acutely aware that their children had their own lives and felt torn between wanting to maintain a close relationship, especially with their grandchildren, while not becoming a burden. Not wanting to intrude can thus limit an elderly adult's level of communication with their families.

PeerCare, in which the responsibility for day-to-day care and social interaction is shared with physically close neighbors, can relieve some of the burden on family members. For example, Gertrude, who relies on her son's family in case of emergency, also reported feeling better knowing that the *Gang of Four* was there for her: *"It is safer, I find."* This self-constructed group provides an effective PeerCare network that allows women with similar issues and concerns to support each other through frequent interaction.

4.1.3. *Extending PeerCare*

In light of our discovery of the Gang of Four's PeerCare relationship, we systematically examined exchanges among other participants so see if we could identify other examples of PeerCare. We found that all participants had friends, neighbors and relatives in their age group with whom they had regular contact. For example, Emily has a daily visit with a friend who lives nearby and the two talk for several hours. Once a week, Françoise calls her friends who live far away, and also makes time to visit friends who live close to her. Christine has regular contact with other members of her club, some of whom she considers friends. Dorothy meets with friends every week to sing in a choir, while Irène and Josie are neighbors and friends and share important and intimate aspects of their lives on a daily basis. Kathy's neighbor is also a close friend, whom she meets regularly throughout the week. Laura, Mary and Nancy also regularly meet each other for lunch, games and other activities. These regular, habitual visits among friends and acquaintances provide the study participants with shared awareness of what is happening in each others' lives.

4.1.4. *PeerCare and communication*

All participants were involved in a peer relationship that provided either *practical support*, such as closing the shutters of the house when sick; *moral support*, such as chatting when feeling lonely; or *safety support*: such as exchanging house keys. Such support is based on regular communication, including phone calls, chats over the intercom and exchanges of letters. Both the mode and the frequency of communication affect how quickly problems are detected. For example, between weekly phone calls, it is easy for Gertrude's cousin to miss that Gertrude caught a cold. On the other hand, Beatrice will probably notice Gertrude's cold in one of her daily contacts via the intercom.

When PeerCare is embedded in regular communication, participants need not explicitly ask for care, since the other person is likely to notice if something is wrong. In addition, little or no stigma is attached to asking for and receiving care, since the exchange is reciprocal. The perception that one is needed is important for reducing feelings of dependence and the burden of care is shared among people with similar needs and capabilities.

These reciprocal exchanges can be compared with the concept of gift exchange and reciprocity discussed in Mauss (1967), Anderson (1994) and Bourdieu (1997). We can consider a message or a particular attention as a gift that is consciously given. The response to such messages can serve as an acknowledgment of this gift, and as a gift in itself. Entering in a gift exchange cycle marks the beginning of an acknowledged relationship, maintained by the exchanges of messages, *i.e.* the communication. The focus of the messages can demonstrate someone's interest in the other person's well-being, whereabouts, mood or stories. This interest can be considered either an invasion of privacy, in which case returning the message will most likely illustrate an unwillingness to exchange such information, or as a sign of

intimacy and concern, in which case the recipient will be inclined to reciprocate the favor. Taylor and Harper (2003) used this concept of gift exchange to understand messaging behaviors among teens. Here, we describe the role that frequent communication plays in establishing and maintaining the shared reciprocal responsibilities in a PeerCare relationship. We suggest that the increased ability to send messages (gifts) to each other provides opportunities for maintaining a reciprocal exchange, thus limiting the feeling of debt and dependence. This is particularly important with respect to the relationships with families, as discussed later in this section.

For the women in our study, *proximity* is a key factor in determining the frequency of communication and the subsequent effectiveness of the potential support. People living in close proximity have access to more information that can be used to evaluate each other's physical or psychological state. During our workshops, many women pointed out the role of voice tone to evaluate someone's state of mind. Other cues perceived from the environment can also be used to evaluate close people's well-being. For example, Mary describes how in her old apartment, her neighbor would check her shutters to make sure she was all right. This assessment was based on her friend's knowledge of Mary's habits: If she usually opens her shutters at 9am, the friend will start to worry if she sees they are still closed at 9:30. This example does not require any conscious effort on Mary's part, but rather relies on her friend's ability to observe and interpret her daily routines. In contrast, Irène sometimes explicitly leaves her shutters open as a signal to her neighbors that she plans to return home late that night. This is a conscious act on Irène's part and relies on her neighbor's willingness to learn and interpret her code directly. Finally, people who live close to each other benefit from the possibility of impromptu visits and the ability to simply observe each other in the course of each other's daily routines.

4.2. Awareness, rhythms and routines

Participants in the study reported having a strong sense of awareness of the daily routines of the people with whom they interacted regularly. For example, when trying to schedule interviews, Beatrice was able to suggest a suitable time for contacting Gertrude, so as not to interfere with her everyday activities. Participants were aware of the activity patterns of their peers and used this knowledge to organize their interactions. For example, Gertrude buzzed Beatrice over the intercom toward the end of our interview. At that point, she revealed that she had waited to contact Beatrice so as not to interrupt our interview.

Awareness of each other's routines depended both upon the intimacy of their relationships and the frequency of their communications. For example, Beatrice and Helen live next door to each other and consider themselves closer to each other than to the other members of the Gang of Four. They share certain mundane activities, such as taking down the garbage together every morning and have

developed an intimate knowledge of each other's routines. For example, Helen told us that Beatrice goes to the gym every Wednesday at 2pm, unless she has a doctor's appointment.

We identified two different forms of awareness of routines. The first involves knowledge of regular events, such as meals or cleaning days. Participants developed expectations about each other and used this information to help organize both face-to-face and other interactions. The second involves knowledge about irregular events, such as a visit from a friend or a medical appointment. Thus, when Josie goes to the doctor, she informs Irène, who visits her afterwards to find out how it went.

4.3. PeerCare, privacy and environmental cues

Maintaining privacy involves important trade-offs. Participants want to both maintain their privacy, especially the integrity of their homes, while understanding the need to disclose somewhat sensitive information in exchange for peace of mind. The members of the Gang of Four explained that despite their strong peer-support relationship, they conscientiously respect each other's privacy. Their relationship is based both on friendship and a reciprocal need for each other. *"We are lucky to have each other"*, explains Gertrude, *"we are all recently widowed, moved from a house into an apartment and we did not know anyone in town before arriving."* In their situation, it is difficult to find people to trust and rely upon with private matters. As Beatrice puts it: *"At our age, we are cautious about who we let into our homes"*. While these women meet on a regular basis, they often do so outside, in order to not abuse each other's hospitality. Another participant, Nancy, adopted a stricter policy in which she mainly meets her friends outside her apartment. *"Some people, if you let them in, they never leave and always come back."*

Some participants mentioned using cues in their environment to discern the status of a neighbor; e.g. the current state of the shutters or if the lights are on. Although such cues may be difficult to ignore, many participants felt that there is a shared tacit agreement that one should ignore such cues unless necessary. Several said that they felt guilty about interpreting these cues and using them in their interactions with their neighbors. For example, Irène usually noted whether or not one neighbor's car was in the driveway or assuming that another neighbor was going to bed late, since the living room lights were still on, but felt slightly guilty about this. In other cases, acknowledging these environmental cues is not viewed as an invasion of privacy, such as when Mary's neighbor agrees to check her shutters to see if she got home safely.

We also noticed that our participants often shared sensible information with each other, often about their health. For example, Irène and Josie inform each other of their respective appointments and illnesses. Similarly, members of the Gang of Four remain aware of similar information through their frequent interactions. When sharing of private information is done willingly, it does not

seem to provoke any privacy issues. Although regarded as sensitive by these women, they do not hesitate to share it in order to ensure a better peer support relationship. Their need for privacy is counterbalanced by their need for care and the reciprocity makes it feel less invasive.

5. Discussion

The next section describes how our findings about PeerCare suggest new possibilities for communication technology that supports aging in place.

5.1. PeerCare

Our study highlights the differences between uni-directional monitoring of the elderly and bi-directional PeerCare. The former concentrates on safety issues alone, whereas PeerCare emphasizes reciprocal social relationships as well. PeerCare provides a socially acceptable alternative to monitoring based on existing social behavior that allows participants to act as both caregivers and as care recipients. A communication technology that supports PeerCare must encourage both *social* and *care* exchanges. *Social exchanges* form the basis for friendship and companionship and include conversations that may have nothing to do with care. In addition to reducing feelings of loneliness and isolation, they also provide the motivation for mutual care and looking out for each other. Social exchanges help people to feel connected and engage in emotional relationships with others. *Care exchanges* may involve giving or receiving care; either explicitly, as when Gertrude calls to see if Beatrice is OK, or implicitly, such as when Irène assumes everything is OK because her neighbor is home. People in care relationships call each other more often when one of them is sick, both to cheer them up, a social exchange, and to offer services, a care exchange. The two types of exchange are often interspersed but each is important for maintaining the other: social relationships provide the motivation for care relationships, and care relationships enhance social relationships.

5.2. Communication, peers, families and gift exchange

Frequent exchanges of messages can help the elderly to establish and maintain strong social relationships with each other. Belonging to strong social networks makes it easier to accept 'being in debt' to someone if something goes wrong, because members trust that such debts can be repaid through social exchanges. As van Tilburg et al. (1995) point out, the balance of these exchanges helps us to understand the nature of dependency and why some elderly fear being a burden to their families. Bourdieu (1997) suggests that if a debt in a gift exchange cannot be repaid, it creates a hierarchy of domination. Thus, if we are to encourage effective PeerCare relationships, it is essential that participants are able to

reciprocate gifts of care among themselves, through both social and care gift exchanges. The challenge is to design communication appliances that maintain and enhance social relationships while providing reciprocal opportunities for care.

5.3. Awareness

Some forms of communication do not involve explicit sharing of messages, but rather involve an on-going awareness of the other person's state. People use both personal and environmental cues to help them interpret what is happening to the other person. *Personal cues* may be involuntary and are derived from a person's behavior or appearance. For example, subtle changes in a friend's tone of voice may indicate disappointment or fear, whereas a change in posture can indicate depression or a recurrent bout of rheumatism. In contrast, *environmental cues* emerge from the local environment. For example, lights shining in the living room may mean that the occupant is staying up late or that she forgot to turn out the lights. Over time, people build up expectations about the behavior of the people around them, based on their perception of personal and environmental cues as well as explicit social exchanges. Participants in social networks become aware of patterns of cues and use their interpretations of those patterns to evaluate each other's state and coordinate interactions accordingly.

Such exchanges work well when people live in close proximity to each other, but become difficult or impossible at a distance. Technology can play a role in bridging this gap, allowing the exchange of subtle personal and environmental cues to mediate the impact of physical distance. *Communication appliances* are specifically designed to facilitate this exchange, providing ambient information via a dedicated, 'always-on' channel. We argue that the perception of patterns of personal and environmental cues can support interpersonal awareness of each others' rhythms and routines.

5.4. Rhythms and routines

Crabtree and Rodden (2004) identified *routines* as regular patterns of use of the space in which people, and particularly the elderly, interact in their homes. Palen and Aaløkke (2006) examined practices based on biological *rhythms*, such as waking up in response to the sunrise or feeling hungry and regular *routines*, which may include *habits*, e.g., John usually picks up his newspaper right after it has arrived, *regular events*, e.g. John receives a caregiver visit every Tuesday afternoon, and *planned events*, e.g., John has an appointment at the doctor's next Wednesday. Many such routines are repeated on a daily, weekly or monthly basis. Palen & Aaløkke noted that the elderly (and their caretakers) used rhythms and routines as natural prompts for keeping track of their medications, e.g., placing a pillbox next to the breadbasket to remember to take the pills at breakfast.

Rhythms and routines play an important role in PeerCare. Our study participants revealed detailed awareness of and knowledge of each other's activities and whereabouts. Many, particularly the Gang of Four, explicitly shared their schedules with each other and talked about expected changes to their routines. Elderly peers tracked and reacted to each other's rhythms and routines, using them to assess given situations and determine whether or not something seems 'normal'. If the observed behavior does not match expectations, it can be viewed as a potential emergency and lead to an appropriate reaction, i.e. giving care.

Communication routines, which consist of regular exchanges with neighbors, friends and family members, play a particularly important role in PeerCare. These routines support the social aspect of PeerCare relationships, allowing members of a social group to keep up-to-date on each other's activities and feelings and contribute to a sense of intimacy and belonging. Communication routines may include a weekly phone call or a two-minute chat via interphone every morning. They may occur regularly as part of a shared activity, such as a weekly scrabble game, or may be irregular, informal exchanges, such as 'bumping into' someone frequently at the supermarket. Still other communication routines involve a third party, such as regularly checking how that person is doing. Some communication routines have a predictable frequency, ranging from several times a day to once a year. Some have predictable durations, from a few seconds to a few hours. Participants in such communication routines are very aware of their role in maintaining social relationships; any disruption is quickly detected and interpreted, for better or worse, by the people involved. Communication routines reflect the participants' commitment to the social relationship, and often highlight the strong ties among the elderly for both friendship and reciprocal care.

Based on these results, we decided to explore how to support communication routines using computer-mediated communication technology. We wanted to provide technology that enhances awareness of routines for members of a PeerCare social group, with two complementary goals: first, to provide a new, bi-directional communication channel to support the *social* aspect of PeerCare and second, to provide a baseline of 'normal' routines, from which unusual situations can be detected, to support the *care* aspect of PeerCare.

6. Technology probe study

Crabtree and Rodden (2004) and Palen and Aaløkke (2006) suggest that observing how people organize their space and their actions in home settings can inform the design of interactive devices for the home. Begole et al. (2002) and Nagel (2006) suggest that routines can help people coordinate their interactions and avoid undesired interruptions both in home and work contexts. Lottridge and Mackay (2009) offer a design method, called Generative Walkthroughs, which specifically incorporates the notion of rhythms and routines, as well as other socio-technical principles, into the redesign process. Real-world scenarios are examined, step-by-

step, to identify established rhythms and routines. These then serve as a basis for generating novel design ideas that explicitly take rhythms and routines into account. In this paper, we are interested in how to design technology that builds upon existing communication routines, or creates new ones, that increase shared awareness, feelings of connectedness and intimacy, and ultimately, support PeerCare.

We conducted a technology probe study (Hutchinson et al. 2003) to assess and understand how communication appliances can support shared awareness of rhythms and routines among elderly peers. Our goal is to establish and maintain *social and care exchanges* that lead to more successful aging in place. We are interested in how to combine active and passive communication to provide shared awareness of both personal and environmental cues that reflect each participant's rhythms and routines. Specifically, we want to create a system that enhances the ability of elderly peers to communicate with and care for each other. Technology probes allow us to explore the design implications of our field studies, test specific design alternatives, inform and inspire future designs. They also serve as the foundation for informed design discussions between ourselves and the elderly participants: because technology probes are tested in situ, participants can provide far deeper insights into how such technologies can be used to interact with each other and share awareness of each other's rhythms and routines.

6.1. The markerClock probe

We designed a technology probe, called markerClock (Riche and Mackay 2007), to help users gain awareness of each other's rhythms and routines at home. Rather than introducing a novel technology into the elder's home, we chose to enhance a ubiquitous and familiar object, a clock, and enhanced it with information about the other person's activity. Each markerClock is designed to be continuously connected to another markerClock via a dedicated channel (Mackay and Beaudouin-Lafon, 2005). This means that each markerClock is both a standard clock and current window into what is happening at the other household. MarkerClocks are symmetric: each participant provides and receives the same information. Activity information is aggregated and distilled into a simple, abstract representation that can be ignored or interpreted by a knowledgeable user. The goal is to achieve a useful balance between protecting the participants' privacy and revealing enough information to support shared awareness of each other's rhythms and routines, leading to both social and care exchanges.

MarkerClock is an augmented clock designed to support general awareness of routines in the home and to establish and maintain lightweight communication routines among participants. To minimize privacy concerns, we capture only a tiny amount of information, i.e. the motion that occurs in front of the MarkerClock, and display it as a colored trace in a concentric ring (Figure 2). Users can also engage in lightweight communication by placing small symbols on the trace. MarkerClock takes advantage of the user's familiarity with the

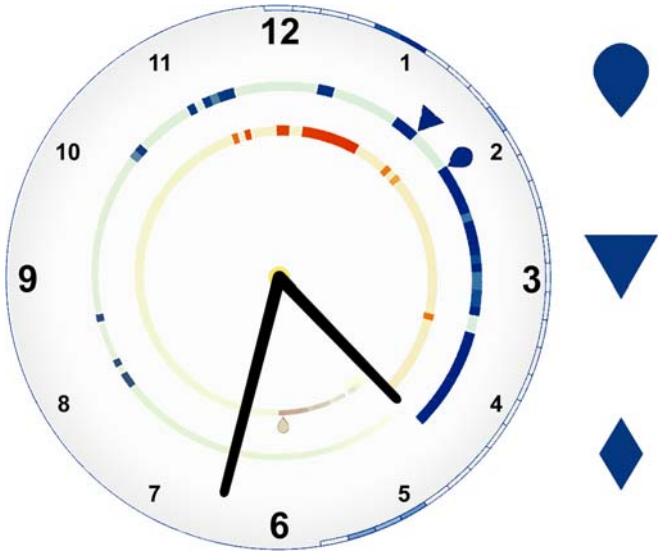

Figure 2. MarkerClock connects two users, each represented by a concentric colored ring.

temporal and spatial layout of clock faces, so that symbols appear at the time one would expect.

Each markerClock includes a webcam. We analyze the resulting feed using a motion detection algorithm to generate a motion value for a specified time period. Values range from 1 (no motion detected) to 5 (maximum motion detected). This value is then displayed on the clock, with successively darker color indicating successively more movement. MarkerClock displays the current value as well as the history over the past 12 h, represented as a colored ring, with varying darkness corresponding to varying levels of detected motion. Figure 2 shows two markerClocks connected to each other. The outer ring (blue) shows the motion trace captured by the markerClock installed at the first home and the inner ring shows the trace captured at the second home. The traces for each markerClock appear in concentric rings and the time of each trace value can easily be read by its position on the clock. For example, at 11:23am, someone walked in front of the markerClock, leaving a darker value at the same angular position the hour hand would occupy at that time (see Figure 1, inner ring).

MarkerClock required a number of basic design decisions, each with implications for the use of the system. First, we chose a single activity indicator, i.e. the motion occurring in front of the device, rather than a range of detectors. This design decision was motivated partly by privacy issues, since it limited the amount of information gathered and displayed, and partly by technical issues, since it was clearly simpler to implement and install. But we could have added many more sensors and triangulated across them to generate more "accurate" activity data. For example, if we added a motion detector and a proximity sensor,

we would have had a more reliable and less noisy signal than our version. Similarly, we could have monitored audio levels or detected the weight in front of the clock, to 'ensure' that a person was really there. However the goal of markerClock is not to ensure that the *system* detects the presence of people in the room as accurately as possible, but rather that the *human participants* use it as a useful communication device. What is essential is that these specific people, in these specific houses, develop a shared understanding of what these specific traces mean. Additional accuracy may, or may not, be relevant.

Second, we chose to make the trace ambiguous, rather than trying to interpret the signal in any way. This offers privacy to both partners, indicating no more than that something is moving in the house: perhaps the user, but perhaps the cat or a curtain near an open window. Ambiguity is important for reasons of 'plausible deniability'; in other words, people may avoid using the system if they believe it reveals too much about them. On the other hand, the specific users of the system bring a great deal of knowledge to the interpretation of each trace. A random visitor may not be able to 'read' the traces on the clock, but Ann will see at a glance that her neighbor Bob is back from his doctor's appointment. MarkerClock is thus designed to leverage the users' existing knowledge of each other's routines and to check that knowledge against what is currently appearing on the clock's display.

It is important to note that, while markerClock's traces are ambiguous, they are not arbitrary. Like markerClock, Romero et al.'s Tableau Machine (2006) records sensor input and displays an ambiguous graphical output. However, in their case, the mapping between input and output is not clearly correlated; there is no way to predict how the system will react to the users' reactions (Pousman et al. 2008). We specifically avoided combining ambiguity with a low-level of interpretation, as in Gaver et al.'s Home Health Horoscope (2007). According to the authors, even though the system collected real data from the house, the process of distilling that information down into a short text (in the form of a horoscope) that was not completely correlated with what they observed themselves, causing the users to mistrust the system (Gaver et al. 2009). In both of those systems, the perceived arbitrariness of the display prevented users from building an understanding of activity history, which is essential for our purpose of establishing awareness of routines. (Of course, neither of those systems were intended as communication devices between distant households.)

Third, we present the activities of both participants, not just the distant partner. By providing users with direct feedback about their *own* behavior, markerClock never seems arbitrary and users quickly develop an intuitive understanding of how it detects and displays information. Anybody can move in front of markerClock and immediately see the effect. This also makes it easy to get an idea of what the *other* person is seeing, and probably interpreting. The direct link between the user's action and the system's display encourages both exploration and trust in the system. The juxtaposition of the two activity traces also allows users to refer to their own

time frame to understand the others' activity. For example, Ann might notice that Bob's activity increases later than hers, indicating that he probably wakes up later than she does.

Fourth, we combine synchronous information exchange with asynchronous communication, via a 12-hour history. This, of course, is necessary if people are to develop a sense of daily routines and to begin detecting patterns that might not otherwise have been visible. For example, Ann may know that Bob's grandchildren often drop by after school, but would discover that this never occurs on Thursdays. (She might be prompted to ask and find out that they take violin lessons that day.) Although we could have chosen a shorter time period, such as the past hour, or a longer period, such as the past week, we felt that 12 h made most sense with respect to the constraints of the clock face and the relevance to people's daily routines.

Fifth, we allow users to place symbols on their traces, as a form of communication. We used three shapes: drop, lozenge and triangle, which had no clearly pre-defined meanings. Participants could create their own symbolic codes over time, using a single symbol or any combination they liked. Again, the goal was not to provide a specific language for them to use, but rather, to provide support for them to create their own form of communication. This approach is similar to that of Kaye et al.'s (2005) Virtual Intimate Object, which lets the partners in a couple exchange a tiny amount of information, essentially clicking on an icon to highlight the partner's icon. Their system also preserves history, since the highlight fades over time, and makes it possible to perceive incoming clicks. Their field study revealed that even the simple exchange of a single bit of information was sufficient for close couples to develop rich interpretations of each others' behavior. We offered slightly more options (three symbols, not one), but our expectation was that participants could build upon this simple foundation to develop practical or whimsical styles of interaction.

We conducted a study of markerClock, using it as a technology probe to explore whether and how elderly participants could use a communication appliance to share simple, ambiguous information about their activity and whether or not this would develop into a communication device and a source of information about each others' routines.

6.2. Participants

We recruited two women, aged 70 and 82, Ursula and Veronique, both living in apartments in Paris. Ursula lives on her own, while Veronique often hosts her grandchildren who are studying in Paris. Ursula recently bought a computer and has minimal knowledge of its use, having only just started using email and browsing the Internet. Veronique has an old computer given to her by her daughter that she rarely uses. Both women meet every 2 weeks with other friends for a discussion around religion and scripture. They also sometimes meet outside this schedule for social events. Their participation in this study was motivated by

a curiosity about the sociological aspects of communication technology and towards the markerClock.

Note: We had discussed creating three markerClocks for three members of the Gang of Four. However, in addition to timing and technical issues, we also felt that it would be more interesting to try markerClock with people who had not been directly involved in its design.

6.3. Method

Prior to deploying the markerClocks, we interviewed Ursula and Veronique to assess their relationship and to get a sense of how often they interacted with each other, both physically and via phone or computer. During the 4-week deployment, we alternated phone and face-to-face semi-structured interviews. We collected self-reported data about their interaction with markerClock, their physical and mediated interactions and the possible influence of the markerClock in their relationship or interactions. We also collected a mix of hand-written and audio recordings of the interviews. Each markerClock logged data, including a complete set of the activity traces for both users and the symbols they sent to each other.

6.4. Setup

The markerClock probes were developed using Trolltech's Qt API for the graphical interface and Roussel's (2001) núcleo video prototyping toolkit for motion detection using a webcam. They were deployed on 20" Apple iMacs fitted with built-in video cameras, capturing images for motion detection. To ensure participants' privacy, no image from the camera was ever recorded on disk.

We initially discussed the location of the probe with participants, so that it fit with their existing home arrangements and to ensure it would be easily visible and capture activities of daily life (Fig. 3). Ursula's probe was placed the probe in her living room, on a piece of furniture close to the door, facing most of the room. After some consideration, Veronique's probe was placed in the living room, facing most of the room, including the dinner table. These placements influenced our results by focusing on activity happening in public spaces of the home (Leonardi et al. 2009), as opposed to being placed in a bathroom or a bedroom. We felt this position would show information with which the other member of the pair would be most familiar.

7. Results

This study explored the question of whether providing users with a simple history of movement from two different households, captured and displayed regularly, could support shared awareness of each others' routines. We were particularly interested in if and how participants used their existing knowledge of each other

Figure 3. The markerClock probe, deployed in a participant's living room during a pilot study.

to interpret the data on the clock and whether it would improve communication between them. We paid particular attention to its impact on their feelings of privacy and whether they used symbols for active communication.

7.1. Supporting awareness of rhythms and routines

Ursula and Veronique had little prior knowledge about their respective routines at home, during the day. They were, however, able to easily deduce when the other got up and when to bed, from the reading of the clock. They reinforced this awareness by using the 'drop' symbol as a greeting, when they each got up in the morning. This symbol also served as a tacit signal for when it was ok to call in the morning, i.e. not before the drop symbol had appeared.

Both Ursula and Veronique were able to identify certain salient events from markerClock. In one interview, when we replayed the traces of the previous week, Ursula pointed out the days when Veronique had had a visitor. Although she knew that Veronique had been expecting a visitor, she had not known exactly when. She was able to infer the exact dates because the traces at meal times were longer. Ursula also pointed out that Veronique's grandchildren tended to get up early, showing a strong trace before the morning greeting.

Veronique grew frustrated by the activity trace, because the location of the markerClock in Ursula's home meant that it was overly sensitive to changes in lighting, with a correspondingly noisy signal. Veronique would see increased activity at times when she knew Ursula was not there, which lead her to call her friend afterwards to relate the event. Although this is a clear example of an annoyance introduced by the device, it also demonstrates that Veronique had a clear enough understanding of Ursula's routines to identify unexpected events and how unexpected events can lead to more direct communication between the participants.

Although Ursula and Veronique were able to infer a few specific events from the motion traces on markerClock, they found it more useful for noticing certain patterns of activity, increasing awareness of each others' routines. They reported that they called each other more often and discussed their respective whereabouts more. Over time, markerClock became part of the daily routine of each participant. They would glance at it upon waking up, and, when ready, greet the other by placing a symbol.

Both women also reported using markerClock as a regular clock, their main device for checking the time. This suggests that the clock metaphor was appropriate for our purposes and integrated well into each participant's existing routines. However, although the clock face became familiar and accepted over time, their initial feedback suggested that they would have preferred to adapt the look of the clock to their own individual style. Aesthetics are a problem for any technology that must fit in a home environment. However, this could be accomplished relatively easily with 'skin's or the ability of the user to choose their own images to better integrate the clock to their decor. The first version of markerClock issued too much light, disturbing participants in their living rooms when they wanted to, for example, watch a movie in the dark. We added a dimmer mechanism, which reduced the light emitted when no motion was detected, but this did not completely solve the problem. Alternative display technologies, such as electronic paper, might provide a suitable alternative to existing LCD displays.

7.2. Awareness versus closeness

Ursula and Veronique reported feeling more connected to each other because of the constant presence of fresh information about each other. While they did not always know exactly *how* to interpret this information, seeing that the trace had changed raised their interests and made them think about each other more often. They reported that they typically looked at the clock four to ten times a day, and noticed changes in each others' traces. Over time, they reported feeling closer, but not necessarily on an empathic level. As Veronique said: *"It brings some comfort, you get more intimate. […] It kinds of brings us closer physically, but not emotionally."*

7.3. Symbolic codes

Ursula and Veronique each used symbols regularly. At the first meeting, they agreed upon an initial meaning for each symbol, but we encouraged them to modify these meanings according to their needs. The first three meanings they chose were: "I'm available", "I'm not available", and "Contact me as soon as you can." This initial vocabulary caused some early frustrations in their exchanges, with respect to availability. At first, they felt required to use both symbols systematically and Veronique started reminding Ursula over the phone that she had not notified her when she had returned from her errands. Both women grew annoyed by this constraint, and at our first weekly interview, we suggested that they avoid using symbols that created obligations for the other. Later, both women decided over the phone that they should relax the meaning of the "I'm unavailable" symbol to mean "do not disturb". This drastically reduced the use of that symbol during the day. Moreover, both participants were already in the habit of sending a symbol when they were available in the morning, approximately after breakfast. Spontaneously, the "I'm available" symbol turned into a morning

greeting. Thus, what was initially viewed as a practical tool for exchanging a message evolved into something more social and creative.

In addition to the aforementioned morning greetings, both women would send multiple symbols during the day. Ursula used symbols every day of the deployment, ranging from one to 47 symbols per day. Veronique also used symbols all but one day of the deployment, ranging from one to 12 per day. We were particularly interested by an innovative use of symbols by Veronique on the occasion of Ursula's 70th birthday. Veronique placed 7 drops on the clock spaced approximately every 10 min to celebrate her friend's birthday (See Figure 4). Ursula reported feeling very happy about this, and that the special effort Veronique had taken meant a great deal to her. Their re-appropriation of symbols is similar to that observed by Kaye et al. (2005) and we expect that, over longer periods of time, participants would develop other creative means of social exchange.

8. General discussion

8.1. Rhythms and routines

Home life is made up of daily rhythms and routines; they provide the foundation for the intimate knowledge that family members and roommates share about each other. Yet such information is often very private and must be rendered ambiguous if it is to be shared with others outside the home. Our studies suggest that communication appliances that are explicitly designed to convey environment or personal cues about routines provide novel opportunities for building shared awareness while simultaneously enhancing social ties and preserving privacy.

MarkerClock demonstrates that capturing an ambiguous trace of activity over the day can enhance the awareness of each other's routines. Participants were able to build upon their respective knowledge of each other to make reasonable guesses about what the other had done and predictions about what was likely to happen next. Participants used markerClock to coordinate their activities and

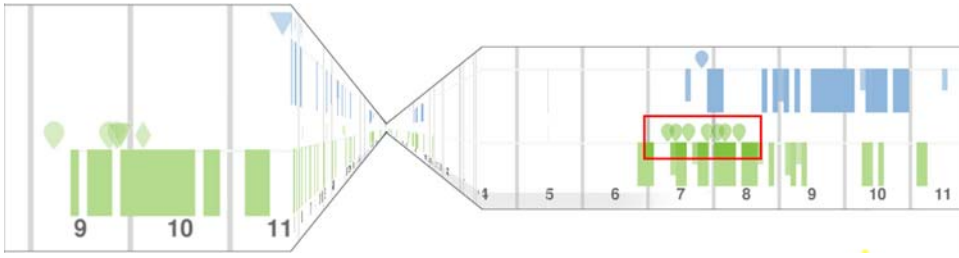

Figure 4. Custom visualization, using the Mélange folding technique (Elmqvist et al. 2008), of Ursula and Veronique's usage log showing a typical morning (*left*) and the morning of Ursula's 70th birthday (*right*).

manage interruptions. Using markerClock also encouraged them to explicitly discuss their routines, not only enhancing their awareness of 'normal' activity, but also strengthening their social ties.

Although we have developed a variety of other communication appliances (Hutchinson et al. 2003; Lottridge et al. 2009), we found that the use of the clock face offers particular benefits for helping the elderly to share awareness of each other's rhythms and routines. Living quarters for the elderly are often smaller and few want additional 'technology' in their living rooms. Replacing an ordinary clock with a markerClock had the benefit of taking up little or no additional space and served as a useful artifact, i.e. a clock, in its own right, without looking like a computer. The clock face provides a familiar mapping between time and space, allowing users to read and easily interpret information, including evaluating time and durations. MarkerClock also helped people to become more aware of their own rhythms and routines and to understand how their activity at specific times was represented by the traces that appeared on the clock.

8.2. Communication appliances to support aging in place

The role of communication appliances as a tool to support aging in place should be considered in the wider context of communication devices and practices. Our study suggests that people who already meet or call each other on the phone can build upon the ambiguous cues from markerClock to generate additional awareness of each other. Just as they extract meaning from the state of a window shutter or a car in the driveway, they also learn to extract meaning from a low-detail motion trace. We want to emphasize that this awareness does not exist in a vacuum, but rather builds upon their existing communication patterns, including phone calls and visits, and their existing knowledge of each other, to create meaning. Cues from a technology like markerClock are fragmentary and difficult to interpret in isolation. Participants require not only existing knowledge of each other but also a social relationship that encourages them to pay attention to markerClock's cues. For communication appliances to help aging in place, it is important that both participants share a desire to know what the other person is doing.

Participants can manage their privacy by explicitly offering or hiding cues. Both participants are aware that this is occurring and assess each other's states accordingly, either consciously or unconsciously. By acknowledging the need for care as one aspect of a PeerCare relationship, participants can use communication appliances to exchange care requests while continuing to feel in control and maintaining their sense of dignity.

8.3. Communication appliances and social connectivity

Although we originally expected that markerClock would increase feelings of closeness between participants, this was not the case for Ursula and Véronique.

They both reported that they felt better informed about what was happening to the other, but that they did not necessarily feel emotionally closer. This is similar to what Lottridge et al. (2009) found when distant couples shared a communication appliance: those who had already lived together found that tiny details about each other's daily lives helped keep them close, whereas those who had never lived together sometimes found such details to be annoying. A communication appliance, in and of itself, is clearly no substitute for direct human-human communication. We saw that markerClock could be a source of conflict when participants used it to demand actions from each other. It could also be a source of comfort, such as daily morning greetings, or of pleasure, such as the Veronique's birthday message to Ursula. However, the actual negotiation of how any communication appliance is used is always based on the emotional relationship between the human participants. For participants who are already emotionally close, a communication appliance can help to maintain that closeness when the participants are apart. But if the participants are not already close, this technology will not enforce it.

Even though they do not guarantee greater closeness, communication appliances can increase feelings of connectedness between participants. This is especially true when the technology serves as a communication medium and not just as a passive trace of activity. Both Ursula and Veronique reported that seeing a symbol from the other triggered additional phone calls and visits. Like the women in the previous study, they reported that they appreciated effort on the part of the message sender. Ursula was particularly touched by the fact that Veronique had sent seven dots on ten separate occasions. This required thought and persistence, and indicated her willingness to expend extra effort to amuse Ursula. A message such as this is a gift, and is viewed as such. Like receiving a hand-written thank you note instead of an email, these women sometimes valued the perceived effort expended more than the actual content of the message.

This has interesting implications for the design of communication appliances, especially those intended to support the social aspect of PeerCare. Rather than seeking the most highly automated communication service, users may prefer higher levels of effort. Enabling people to express their commitment to each other via message exchange can serve as additional motivation for using a communication appliance. Allowing users to exchange messages as gifts also has implications for the *care* aspect of PeerCare. People negotiate their relationships and decide when and how much potentially sensitive data to exchange. We suggest that participants might be more willing to exchange detailed information about their routines, their well-being and their health, if they are in a reciprocal arrangement that includes social as well care exchanges. This allows them to avoid the stigmatization of feeling dependent and unneeded: PeerCare participants who use communication appliances should be able repay care debts through social exchanges, and benefit not only from care, but also from feeling appreciated and needed.

8.4. PeerCare versus monitoring

We have shown how markerClock can be used as a communication device, in which participants leave explicit symbols as messages for each other. However, the other key function of a communication appliance is the passive sharing of information about each participant's activity, based on sensor input. This is similar, in some respects, to monitoring applications that use sensors to detect an elderly person's activity. However, from the user's perspective, the two approaches are fundamentally different. MarkerClock is designed to facilitate extremely lightweight bi-lateral communication and sharing; 'monitoring' is a side effect that *both* participants can use for care exchanges. The information is fragmentary, ambiguous and open to interpretation. Interpretations rely heavily on the participants' knowledge of each other's routines and traces alone provide very little information. As a result, markerClock can function as a monitoring device if the participants are willing to share the information necessary to interpret it, but it leaves them in control and does not make them feel like 'big brother' is watching them. Participants know that the activity trace is susceptible to anomalies, such as a cat passing or a curtain moving, and interpret it accordingly. This ambiguity permits deniability, and, like Aoki and Woodruff (2005), helps users manage their privacy without a loss of face.

All of this is in stark contrast to monitoring approaches, which focus on helping one or more outsiders to detect problems with the elderly. Activity information is either interpreted by a computer system, e.g. detecting a fall, or by an adult child or care giver who seeks abnormal patterns that might require care. Elderly participants have no contributing role, except as a source of data. We suggest that shifting to a PeerCare approach can address some of the ethical issues inherent with monitoring and also increase the willingness of the elderly to actually use these systems. Monitoring approaches require immediate loss of privacy in exchange for potential care in the future. PeerCare offers immediate social benefits, without requiring loss of dignity, allows participants to feel needed as well as dependent, and still offers the potential for care, if needed, in the future.

9. Conclusion

This article introduces the concept of *PeerCare*, in which elderly neighbors develop small social networks that involve both social and care exchanges. We argue that technology to support PeerCare, i.e. simple, pleasant-to-use mediated communication technology called *communication appliances*, can let elderly participants 'keep an eye out for each other', and help them to build and maintain the social networks that ensure both their safety and their mental well-being. Our study of 14 women suggests that the elderly often develop PeerCare relationships on their own, developing a shared understanding of each other's rhythms and routines that allows them to interpret even very minimal shared information. Our

study of the markerClock technology probe suggests that sharing low-content, ambiguous data, when combined with a knowledge of each other's rhythms and routines, can enhance shared awareness without a significant loss of privacy.

We argue that in many cases, communication appliances offer a more acceptable alternative to uni-directional activity monitoring strategies and are thus more likely to be used by the elderly who want to age in place. Communication appliances offer many of the benefits of monitoring, without the associated problems of lack of privacy and reciprocity. Of course, communication appliances such as markerClock can only be effective in supporting PeerCare when used in conjunction with other forms of communication, especially face-to-face interaction. We do not claim that increasing shared awareness will necessarily increase emotional closeness, since the latter is based on the complex set of interactions that make up human relationships. However, we do believe that communication appliances, if the participants view it as lightweight, unobtrusive and enjoyable, can help to maintain social relationships and simultaneously provide a shared sense of 'normal' behavior from which abnormal situations requiring care may be detected. Supporting PeerCare through communication appliances thus offers a novel way of improving the elderly's ability to safely remain at home, allowing them to both offer and receive care in the context of their own local social network.

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