DEVELOPING TECHNOLOGY TO SUPPORT THE FUNCTIONAL INDEPENDENCE OF OLDER ADULTS*

ELIZABETH D. MYNATT AND WENDY A. ROGERS

Maintaining functional independence is a high priority for many older adults. Often, staying in their own homes is key to such independence. Computer technology has the potential to assist in this goal by supporting the everyday tasks of older individuals, as well as by aiding caregivers and family members. Our research in advanced computing technologies explores how computational capabilities can enhance day-to-day activities. The computer is not a tool to be picked up, used, and then set aside; it is a constant partner in daily activities. The challenge is to design interfaces that reflect and support ongoing activities of daily life but not be inappropriately intrusive. The purpose of this paper is to provide an overview of the issues that must be considered to ensure success of these development efforts, including older adults' attitudes towards technology as well as their needs and capabilities. We present two illustrative example projects: one designed to meet daily awareness needs of adult children concerned about the well-being of a senior parent, and another that can provide surrogate memory aids for household tasks. These examples demonstrate the complexity of the issues involved in designing the computationally capable home of the future and provide direction for future research and development efforts.

Mr. D. has Alzheimer's disease and has a tendency to wander outside of his home (which is on a busy street with a lot of traffic). However, Mrs. D. can feel comfortable leaving him alone while she bathes because her "Aware Home" will tell her if he is about to go outside and she can say, from the tub, "Latch the front door" and the door will be latched. She can also say, "Dear, why don't you go back to the living room and watch TV," and her husband will hear her because the house knows where he is and can play the message in the appropriate room and at a volume loud enough to compensate for his hearing loss (because the house also knows that Mr. D. neglected to put on his hearing aid that morning).

Mrs. R. appreciates that she is still able to live in the same home where she raised her children and where she has significant ties to the local

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community. However, her children and grandchildren all live in different cities. She's glad that the younger kids have a "magic" box that allows them to take pictures of small objects such as drawings, clay sculptures, even their pet frog, and send them to her. She can peruse them on her digital lap desk and show them off to her friends.

Mr. J. has been having memory problems lately. Sometimes, while preparing dinner, he forgets what he was doing; his memory problems are exacerbated if he is interrupted in the middle of his preparations. Fortunately, Mr. J.'s kitchen is equipped with a reminder system—he simply needs to glance at the visual display mounted by the countertop to see images of his recent actions. By touching the display, he sees and hears additional visual and auditory cues that help him to regain his place.

Mrs. L. has not been feeling well for the last three days. In fact, she has barely gotten out of bed—just long enough to go the bathroom and once to get something from the kitchen. Mrs. L.'s son is on the way to see her because he is worried—he knows about the reduced activity levels of his mother because he has a receiver in his own home that displays information (with approval from his mom of course) about Mrs. L.'s changes in patterns of behavior. Mrs. L. is typically very active so her reduced level of activity may signal an illness.

A primary goal of many older individuals is to maintain an independent lifestyle (Willis, 1996) and many older adults live in private homes, either alone or with family (Smith, 1990). However, individuals will have difficulty aging successfully in homes that are not designed to meet their changing needs and without access to appropriate technologies (Coughlin, 1999). Quite simply, "Staying put is contingent on the livability of the dwelling unit" (Lawton, 1997, p. iii). The vignettes above illustrate how technology can be used to augment the home to support the activities of the older individuals living in that home. Although such technologies are not currently available in today's home environment, they are being developed in research laboratories in many countries.

The purpose of this paper is to provide an overview of the issues that must be considered to ensure success of these development efforts. We will first provide a brief discussion of home technologies, and then review research on the use of technology by older adults including their attitudes, needs, and capabilities. To illustrate the potential for technologies that support the daily activities of older adults, we will present details about two current projects: one designed to meet daily awareness needs of adult children concerned about the well-being of a senior parent, and another that can provide surrogate memory aids for household tasks. These examples demonstrate the complexity of the issues involved in designing the computationally capable home of the future and provide direction for future research and development efforts.

Supporting the Independence of Older Adults

Older adults prefer to "age-in-place," to remain in their own homes for as long as they are able to take care of themselves (e.g., AARP, 2000; Shafer, 2000). From a societal perspective, it is also cost-effective to support their preference. Data from a study in the United Kingdom, for example, suggest that private residential living costs only 55% of the costs of full-time residential care (reviewed in Tang & Venables, 2000).

Community-dwelling older adults must be capable of performing Activities of Daily Living (ADLs) such as bathing, toileting, and eating. In addition, successful independent living requires the capability to carry out Instrumental Activities of Daily Living (IADLs) such as managing a medication regimen, maintaining the household, and preparing meals of adequate nutrition (Lawton, 1990). Existence as an independently living, active older adult may also require the ability to adapt to a changing environment. The willingness to accept new challenges and to engage in lifelong learning may be key to staying fully functional and maintaining a high quality of life. These additional behaviors of active elders have been labeled Enhanced Activities of Daily Living (EADLs; Rogers, Meyer, Walker, & Fisk, 1998).

How can technology be used to support the functional independence of older individuals? A potential starting point is to understand the primary reasons why older individuals transition from living in their own homes to assisted living (residential care) facilities, and to nursing homes. Of course, there are myriad reasons. Predictors of institutionalization include: "the conditions and needs of the elderly person, [and] numerous caregiver and family related issues" (Naleppa, 1996, p. 88). However, individuals living in assisted living facilities typically need assistance with ADLs and IADLs (National Center for Assisted Living, 1998). Augmented environments could potentially support these activities. For example, bathing could be aided by systems that assist individuals getting in and out of the tub, control temperature regulation, and monitor the vital signs of the bather for potential problems. Medication adherence can be supported by external cues or strategies used by the patient to enhance medication-taking behavior (Park & Jones, 1997).

Functional independence, however, involves more than the ability to perform ADLs and IADLs. For many older adults, their daily activities include EADLs such as social communication, continuing education, community volunteering, and part-time work (Rogers et al., 1998). Such activities should also be supported as much as possible by the technological supports built into future generations of homes (Czaja, 1997). For example, communication with family and involvement in leisure activities can be accomplished via the Internet and other communication technologies.

Homes of the Future

The idea that intelligence can be designed into the home to support the activities of the people living there is not new. Simple examples of technology supports designed into home products and systems include sensor lights that turn on when one enters a room, programmable thermostats that enable differential temperature settings throughout the day, and alarms that respond to the opening of a window or the presence of smoke. Current research efforts move well beyond these examples to provide the home with the intelligence to support complex activities such as those illustrated in the vignettes in the opening of this article. Such efforts are referred to as "smart" homes, or domotics, and discussions of some of the prototypes are available on the World Wide Web (e.g., www.smart-homes.nl; http://www.sentha.tu-berlin.de/; www.stakes.fi/cost219/smarthousing.htm; http://www.gdewsbury.ukideas.com/; http://www.cc.gatech.edu/fce/ahri/index.html).

For these efforts to be successful, we should not ask the question "What can computing power do?" Instead we must ask the question, based on human capabilities and social needs, what should computing power be designed to do? We need to a) consider the degree to which older users will be accepting of technological supports for their daily activities; b) understand the capabilities and limitations of older adults including psychosocial needs as they relate to home-based situations; and, c) develop designs from a user-centered perspective.

Technology and Aging

Acceptance

Older adults are willing to use new technologies, contrary to some stereotyped views. Older adults are more accepting if they are provided with adequate training (Rogers, Cabrera, Walker, Gilbert, & Fisk, 1996) and if the benefits of the technology are clear to them (Melenhorst, Rogers, & Caylor, 2001). In a National Science Foundation sponsored study of the Internet community SeniorNet (www.seniornet.org), researchers found that older adults were willing and capable of learning new computer skills. More important, older adults were able to creatively use Internet tools, such as home pages and newsgroups, to support different modes of interaction and social exchange than what is typically found on the Internet (see also Czaja, Guerrier, Nair, & Landauer, 1993).

The primary predictors for participation in SeniorNet were motivation for communication (with family and other seniors) and previous exposure to computers in the workplace (Mynatt, Adler, Ito, Linde, & Day, 1999). In fact, previous experience with technologies has often been shown to predict willingness to use new technologies (Czaja & Sharit, 1998; Rogers et al., 1996). One implication of these findings is that the more we can incorporate technologies into the homes of high-functioning older adults, the more willing they will be to use more advanced technological supports as their capabilities decline.

Older User Capabilities and Limitations

"Demographic changes make it vital for designers to become aware of the nature and extent of age changes in physical, sensory, and cognitive abilities. The fact that these changes are complex, and interact with each other in subtle ways, makes their study intellectually fascinating as well as humanely useful. The goal of helping each other to enjoy independence during the extra years that medical and social advances have won for us is surely as rewarding as concentrating on increasing sales and market penetration. Further...these goals are entirely compatible." (Rabbitt, 1992, p. 137).

Understanding age-related changes in motor movement, sensory processing, and cognitive functioning will be critical for the design of effective systems and home modifications. There is a general consensus that as people age, motor behaviors change such that, compared to younger adults, older adults take longer to make similar movements, their ability to maintain continuous movements declines, coordination is disrupted, and movements are more variable (Vercruyssen, 1997). These changes have direct bearing on the ability of older individuals to control devices or to manipulate small components.

Age is associated with changes in all sensory abilities; the most-studied age-associated sensory changes are vision and audition (Schneider & Pichora-Fuller, 2000). Color vision, contrast sensitivity, and visual acuity all decline with age. The presentation of auditory information may be a useful method to compensate for age-related declines in visual functioning. However, there are also age-related auditory changes. Age differences in hearing acuity include loss of absolute sensitivity, differential sensitivity, difficulty detecting sounds of high frequency, changes in pitch, and speech perception.

The field of cognitive aging has made a lot of progress in understanding the basic cognitive changes that accompany the normal aging process (Craik & Salthouse, 2000; Park & Schwartz, 2000). Some abilities do decline, yet other abilities remain intact well into the seventh or eighth decade of life. Of course there are substantial individual differences in the rate of decline and the amount of decline. In general, aspects of memory (e.g., keeping a lot of information active in working memory), online reasoning ability, and aspects of attention such as attending to more than one source of information all show age-related declines. Abilities that tend to remain intact into old age include some aspects of memory (e.g., recalling well-learned information), verbal abilities such as vocabulary and reading, and some aspect of attention (e.g., focusing on a single source of information). Designers must recognize and accommodate those abilities that do decline while at the same time capitalize on the abilities that remain intact.

Need for User-Centered Design

Designers must take care not develop technologies for which there is not a need. That is, if home technologies are to be successful in supporting the independence of older adults, they must be designed with the needs of those older adults in mind. "Needs arise from the ways in which people perceive their everyday world and how they decide and act upon their own self-determined priorities. The ways in which needs arise thus depend upon the individual, but are also driven by the norms shared with other people within their social group...technological solutions must adequately account for the full complexity of human experience if they are to be useful" (Sixsmith & Sixsmith, 2000, p. 192).

Unfortunately, designers sometimes believe that they are representative of the user population and will be able not only to understand user needs but also to predict and rectify usability problems themselves; this is known as the "Egocentric Intuition Fallacy" (Landauer, 1997). It is actually very difficult to foresee the usability problems that individuals will have when attempting to interact with a system. The idea that user input is not needed until after the initial design phase is incorrect (and inefficient) for users of all ages, but perhaps even more critical when the designers are aged 20-40 and the users are aged 60-80. These designers cannot possibly imagine the goals of these users, their motivations, their previous experience (or lack thereof) with various technologies, or the motoric, sensory, and cognitive declines that may impact their performance.

Interviewing users to gauge their preferences is a good starting point for any design, but designers must be aware of the fact that what users say they want is not necessarily what will enable them to best use the system. Reported user preferences should always be empirically tested by observing the performance of users (e.g., Ellis & Kurniawan, 2000). Formative evaluation (during the design phase) and summative evaluation (evaluation of prototypes) are both critically important for ensuring that the final product is usable and useful for its intended user population (Landauer, 1997).

The basic guidelines for designing usable systems are: early and continual focus on users, empirical measurement and user testing, iterative design, and integrated design that incorporates all aspects of usability (Gould, Boies, & Ukelson, 1997). The older adult user population has unique needs, capabilities, and limitations that must be considered throughout the design process. "Needs assessment and requirements analysis are the most important activities for initiating system improvement because, done well, they are the foundation upon which all other activities build" (Beith, 2001, p. 14).

One method for increasing the usability and usefulness of any product is to adhere to principles of universal design. Universal design is an approach to creating everyday environments, products, and technologies that are usable by all people to the greatest extent possible, regardless of age or ability (Mace, Hardie, & Place, 1990). Universal design involves a fundamental shift in thinking away from the idea of overcoming environmental barriers for a particular group of people (i.e., older adults) to a way of promoting participation and integration of the environmental needs of all users. An advantage that universal design brings to this work is that early adoption of home technologies by younger adults will help ensure their availability and expectations of use by those same adults as they age. Moreover, as many transitions from community dwellings to assistive care institutions occur during a crisis period (Naleppa, 1996), prior placement of assistive technologies in the home will be critical to sustaining or resuming functional independence following a crisis period.

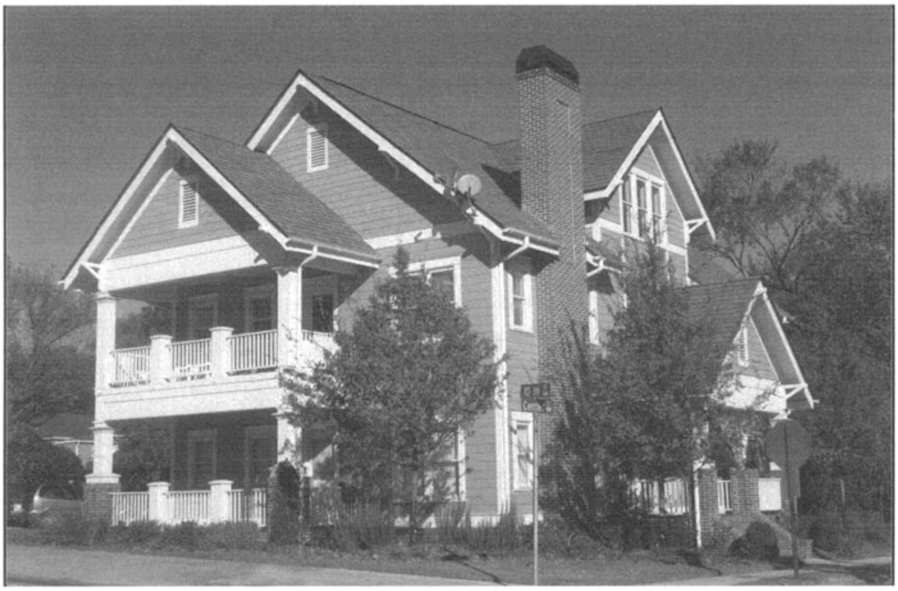
An "Aware" Home: Illustrative Examples

To illustrate how we are trying to develop future home technologies that could aid older adults in retaining their functional independence in a home setting, we will describe two examples. The first project examines the need for monitoring the well-being of an older adult and communicating that information to extended family and caregivers who live in a different location. The second project explores the design of a memory aid to compensate for declines in retrospective memory capabilities. Both investigations are part of an on-going set of research projects and are at different stages of maturity. In this article, they serve as illustrations of the potential synergy of understanding the needs of older adults, designing new forms of human-computer-human interaction, and harnessing sensing (i.e., "aware") technologies.

Both projects rely on some form of sensing infrastructure in the home environment. At Georgia Institute of Technology, this research is being conducted in the Broadband Institute Residential Laboratory (pictured in Figure 1). This house, referred to as the Aware Home, is approximately 5000 gross square feet, and has two identical floors, each equivalent to a typical three-bedroom apartment, allowing comparison studies. It is built with all the functional and design requirements of a normal home, as well as with facilities for instrumenting each and every room with sensors and displays to support ubiquitous interactions between the residents and the house. As part of a multi-disciplinary group of researchers, we are installing a wide range of sensing equipment (cameras, microphones, infrared, radio frequency, sonar, tactile), including general metering on utilities, as well as specific instrumentation on appliances. The goal is to automatically and unobtrusively measure activities of the residents and provide support for their daily needs and activities.

Figure 1

The Broadband Institute Residential Laboratory at Georgia Institute of Technology, referred to as the Aware Home.



The Digital Family Portrait

The Need for Peace of Mind. The desire of older adults to remain in the familiar setting of their family home frequently must be balanced with their extended family's desire to keep them safe. Clearly this balance becomes more precarious as age increases (Naleppa, 1996). Moreover, key events may trigger family members to reassess the likely safety and security of aging parents. A medical crisis, such as a broken hip, may force family members to investigate short-term and long-term care options. Often an aging couple can support one another, but if one becomes incapacitated, can the other provide sufficient support? No longer can family members have the peace of mind that derives from knowing that one aging parent can support the other.

Additionally geographic distance between extended family members exacerbates the problem by denying the casual daily contact that naturally occurs when families are co-located (Mynatt, Rowan, Craighill, & Jacobs, 2001). An anecdote can illustrate the degree to which simple environmental cues can support awareness of family members' well-being. One person we interviewed claimed that, because he lived next door to his father, he could look out his window in the morning to see if his father's newspaper was still on the front walkway. If it had been picked up, he could assume that his father was up and about and was doing okay that morning. This instance illustrates how environmental cues can provide valuable information. Harnessing technology to provide a means of remaining aware of a distant family member's day-to-day activities can promote the *peace of mind* necessary for those senior family members to remain independent in their own homes.

The information and emotional needs of extended family members should not be discounted in an overall approach to supporting the functional independence of older adults. We interviewed chaplains at institutional care settings, who reported that, in their experience, the adult children of older adults play a primary role in making the decision for a parent to move out of an independent setting (Mynatt et al., 2001). This view is supported by a study of residential home care entry showing that for 52% of the cases, an adult child was the primary caregiver prior to placement in the facility (Bear, 1993). Placement decisions may be based on current (and possibly short-term) ailments, but transitions are also motivated out of a concern for *potential future* events that would threaten the safety and well-being of an older adult.

Design Details. The Digital Family Portrait is an in-home monitoring system to inform family members about an older relative's daily activities, health status, and potential problems, as well as information about patterns of activities over a period of time. The Digital Family Portrait creates a visualization of the older person's day at home from available sensor information and displays the information to a family member in a different location. This Digital Family Portrait is created by framing a flat panel display and connecting it to a standard personal computer. Various sensing technologies (e.g. radio frequency badge tracking and computer vision) can gather information about the individual pictured on the display and be integrated into the interface. The current design presents iconic imagery summarizing four weeks of daily, household life.

Shown in Figure 2, the default display of the Digital Family Portrait illustrates the relative activity levels of the older woman pictured in the center. Each butterfly depicts one day of information. The current day is white and time proceeds clockwise around the frame; in other words, yesterday is one step counter-clockwise. Four activity levels can be differentially depicted. The sizes of the butterfly icons were verified in a laboratory setting to ensure that they were discriminable from each other by able-bodied adults that are typical of adult children caregivers who would primarily be using the portrait. The portrait is designed to be persistently displayed in a home environment and to be interpreted with minimal effort.

By touching the butterfly for a particular day, the viewer can see more details about that day and that individual. As shown in Figure 3, the detail screen includes information about the weather at that location as well as the indoor and outdoor temperatures. These simple pieces of information can be significant in assessing someone's behavior; for example, having a slow day when it is raining outside. For this portrait, the woman's activity is measured based on her movements between rooms in her home. This information is summarized in the bar graph shown at the bottom of the screen. Rooms are color-coded and the number of transitions is summarized in fifteen-minute

Figure 2

The Digital Family Portrait. Figure 2 illustrates 28 days of activity information about the woman pictured.

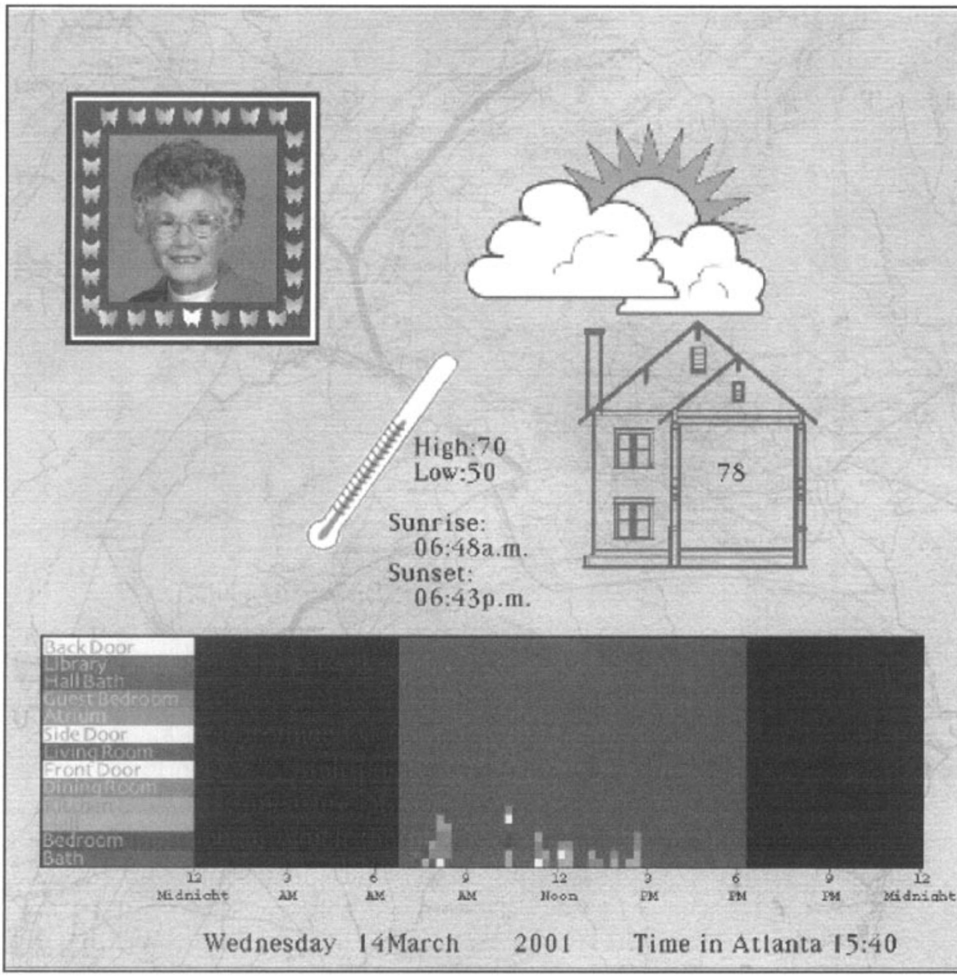
intervals. Daylight and nighttime hours are indicated via the background shading. Although these details are available, the visualization can also be quickly read, for example, noting numerous trips to the bathroom during the night, or perusing the overall flow to the day. We are currently experimenting with techniques to help viewers answer the general question: "Was today a typical day for my [father, mother, aunt, grandmother ...]?"

Technically, the hardware configuration used for the Digital Family Portrait is not substantially different from various Internet photo frames available in the commercial marketplace as well as other forms of information appliances. The portrait assumes that some sensing infrastructure is available and that the information from the sensors can be transmitted to the portrait, including the use of encrypted Internet technologies, to reach the remote family members.

Design Goals. The main design goal of the Digital Family Portrait was to support awareness of the long-term health, activity, and social well-being of senior adults living by themselves, answering questions such as "Has she been eating enough?" and "Is he active or sedentary?" For example, a display on an adult child's bookcase could provide a qualitative sense of the activity of his elderly mother. We believe that this day-to-day awareness is key to

Figure 3

Figure 3 shows detailed information about one day including the weather, indoor and outdoor temperature, and the number of room-to-room transitions in 15 minute increments.



providing peace of mind for family members concerned about an elderly relative who potentially lives far away from them.

To meet this need, the Digital Family Portrait provides a qualitative sense of a person's daily activity and well-being from available sensor information, such as wearable medical sensors or sensors located in their home. Like a traditional portrait, it is designed to be hung on the wall or propped on a mantle, blending with household decorations. Instead of a static frame, the digital frame changes daily, reflecting a portion of the person's life. From general measurements of activity, to indications of the weather, the portrait attempts to capture the observations that would naturally occur to someone living in the same home or neighborhood.

Not surprisingly, most families have different information needs. Based on our interviews and field trials with families, we have collected requests for information ranging from knowing whether someone has collected the daily mail, is correctly taking their medication, or is remaining sedentary following surgery. The visual and computational design of the Digital Family Portrait allows different types of information to be "plugged in" to meet these different information needs (Mynatt et al., 2001).

Most awareness interfaces only provide a snapshot of the present. However, many questions about an elderly parent refer to trends over time, such as "Is she becoming more socially isolated?" or "Have his movements been dramatically reduced since he had that fall?" Consequently, the Digital Family Portrait provides representations of the past, as well as the present.

The Digital Family Portrait must meet emotional and social needs in addition to pure informational needs. For example, the portrait should provide appropriate assurance without triggering additional anxiety. For this reason, colors in the visual display are not associated with changes in the well-being of the older adult, such as the display fading to a dismal gray on a bad day. Socially, the portrait is designed to play a role in family communication and awareness, but not to portray a complete and medically official record. As the sensing infrastructure will only have incomplete knowledge about the senior adult, its visual display should mirror that uncertainty. A regrettable unintended consequence of a portrait that attempted to present an all-encompassing depiction of someone's life would be the reduction of other social means for care-taking such as phone calls and paying attention to outside events, such as the death of a friend, that influence daily behavior.

The portrait is not designed to respond to crisis situations, such as a medical crisis that demands immediate emergency attention. That type of information should be readily sent to a cell phone or some other notification mechanism. Instead, the portrait is designed to convey a longer-term and holistic view of an aging family member.

Assessment. We have combined field observations and interviews, iterative design, empirical evaluations and field trials with the prototype portraits to create an interface that conveys salient aspects of everyday life, complements existing communication practices, creates an emotionally-engaging experience, and respects self-presentation and privacy needs (Mynatt et al., 2001).

It is important to note that there are two groups of users of the portrait. The primary users are the adult children, or other family members, concerned about the well-being of an older adult who resides some distance from them. The secondary users are the older adults whose data are captured by the system and shown in the portrait. The majority of our assessment activities have examined this information exchange between older adults and their family members. An open question at the outset of this work was whether a compromise of information needs and privacy concerns was feasible. Based on interviews with families, this compromise seems quite reasonable although the variety of information needs of different families is daunting.

One question is what information should the older adult receive in return. In a field trial with an earlier prototype, we experimented with reciprocal displays; namely that the older adult would own a portrait that displayed information about a family member, in this case, her grandchild. Although the portraits were welcomed and successfully used by all family members (older adult, her daughter, and her granddaughter), a reciprocal system may be less realistic as it requires multiple sensing infrastructures. However, such a system had the potential added benefit of increasing the communication capabilities and social involvement of the older adult.

Surrogate Memory Systems

Need for Memory Supports. Two common cognitive declines that accompany aging are forms of memory: 1) working memory, that is, the ability to maintain information actively as it is being processed, and 2) episodic memory which is the ability to store new memories of events (Zacks, Hasher, & Li, 2000). Together these impairments impact an individual's ability to perform, particularly to complete, common household tasks (Smith, 2001). Many daily life activities rely on these memory processes and the consequences of age-related declines may be exacerbated if the older individual is distracted or interrupted. Simple examples include remembering whether detergent has already been added to the laundry, if the bathtub water has been turned on, which ingredients have been added to the dinner being prepared, and so on.

A strategy for minimizing impairments in performance due to memory deficits is to provide records of recent actions that serve as a surrogate memory enabling an individual to resume an interrupted task. This recording function is a reasonable task for computational support as computers can be programmed to visually capture a series of events, and even select key frames to depict those events, without needing to understand those events or provide prospective memory support by identifying likely goals.

Design Details. Our current prototype system, called "What Was I Cooking?" provides surrogate memory support for general cooking tasks. The current design emphasizes the temporal order of cooking events. Visual snapshots of cooking actions are arranged as a series of panels similar to a comic strip. Cameras are mounted in several unobtrusive locations, such as beneath a cabinet, overlooking a countertop. Visual snapshots from this angle emphasize the detailed activity of hands and objects while minimizing content, such as faces, that often exacerbates privacy concerns and general discomfort with visual sensing. In the current version, six images are shown in order with the upper left being the oldest and the lower right being the most recent.

A central question in this research is determining what metrics should govern the update rate for the visual snapshots. Examples at the extreme are obviously wrong, such as replacing a picture at either every second or at every hour. Most likely, methods for grouping snapshots are needed to pinpoint salient events. For example, three minutes worth of mixing can be characterized by one image while the brief action of adding salt would need to be depicted. Known image analysis techniques should be sufficient, because the system does not have to recognize a particular action, but must be able to group action sequences and select clear representatives (Boreczky, 2000). We are experimenting with methods that convey the length of time associated with a snapshot. For example, the relative size or prominence of the image could be positively correlated with the amount of time taken for that activity. Again, a goal of this design is to allow the user to survey the contents at a glance, in contrast to, for example, requiring the user to read timestamps or other textual or numeric information.

It is unclear whether a simple temporal ordering of images is the best organization to support memory losses. Other arrangements are possible. Cooking is organized both spatially and temporally, and, although potentially guided by a recipe, people often improvise both in the order and form of their actions (Suchman, 1987). A spatial arrangement could mirror, and thus reinforce, the user's spatial division of work. For example, multiple displays could be directly associated with certain physical locations, such as the stovetop, left or right countertop, or the refrigerator. Another option is a semantic arrangement based on classes of cooking actions, such as grouping together images associated with heating, chopping, cleaning, and measuring respectively.

Design Goals. The primary goal of the system was to provide an ongoing record of recent cooking activity. Its design was motivated by Norman's distinction between knowledge in the head and knowledge in the world (Norman, 1988). By adding information to the world in the form of a visual record, the system decreases the cognitive demands of the cooking task, namely the recall of recent actions. Ideally, users would integrate these snapshots with existing information in the world, such as discarded eggshells or a measuring cup with a trace of flour, so that with little conscious effort, they would fill in any gaps in their retrospective memory. A less-than-ideal, but still workable system, would require the users to interact with the display to retrieve greater detail about past actions. For example, by selecting an image of the act of measuring sugar, the user could determine that two, but not three, cups of sugar had been added to the mix of ingredients.

Assessment. We are in the process of evaluating the utility of our current prototype with young adult users to establish a baseline of performance changes. While making a batch of cookie dough, participants are interrupted with secondary tasks, such as answering the phone, that remove them from the physical cooking location. In the comparisons between the control group and the participants working with the surrogate memory interface, we are measuring the resumption times following interruptions, total time to complete the task, and the number of missing and repeated steps. Although the end goal of this system is to support older users, we are encouraged by an overall positive response to the system and its perceived utility for harried parents and other distracted cooks. One advantage of universal design is that the early adoption of these technologies by younger adults will help ensure their availability and use by those same adults as they age.

Conclusions

As illustrated by these two examples, we are attempting to develop technologies that can contribute to the independence of older adults living in their homes. We recognize that older adults have unique needs and, within the older adult population, there are individual differences in preferences, experiences, and abilities. Consequently, technologies must be adaptive. Our current efforts have also demonstrated quite clearly that much remains to be learned if home technologies are going to be supportive of older adults.

As expressed by the National Research Council (2000) future aging research must focus on "Developing the knowledge needed to design effective technologies to support adaptivity in older adults" (p. 35). For such a goal to be realized "it requires integrating behavioral science and engineering in a context of product design and development" (p. 36). Collaborative research in computational perception, computer science, geriatrics, cognitive aging, human-computer interaction, sensory, cognitive and mobility abilities, and housing will be needed to design technologies to meet the needs of older adults.

Our research in advanced computing technologies explores how computational capabilities can enhance day-to-day activities. The computer is not a tool to be picked up, used, and then set aside; it is a constant partner in daily activities. The computer could notice when you are interrupted and help you regain your task. It could monitor your environment, and inform you of useful information. It could help you schedule your day to coordinate virtual visits from health care personnel and actual visits from family and friends. The challenge is to design interfaces that reflect and support on-going activity of daily life but that are not inappropriately intrusive.

Technology to support the functional independence of older adults will be accomplished through:

- Understanding the older adult as a whole person including sensory, motor, and cognitive capabilities and the interactions of age-related changes in these areas;
- Considering the older adult in a broad context as part of a larger social unit;
- Evaluating older adults in relation to their physical environment; and
- Developing universally designed home-based technologies.

Biographical Notes

Corresponding author: Wendy A. Rogers, School of Psychology, Georgia Institute of Technology, Atlanta, GA 30332-0170; wr43@prism.gatech.edu; phone: 404-894-6755; fax: 404-894-8905.

Elizabeth D. Mynatt is an Assistant Professor in the College of Computing at the Georgia Institute of Technology. Dr. Mynatt received her Ph.D. (1995) in computer science from Georgia Institute of Technology. Her research program in "Everyday Computing" examines the human-computer interface implications of having computation continuously present in many aspects of everyday life.

Wendy A. Rogers is a Professor in the School of Psychology at Georgia Institute of Technology in the Engineering and Experimental Psychology Programs. She received her Ph.D. (1991) in Experimental Psychology from Georgia Institute of Technology. Her research interests include skill acquisition, human factors, training, and cognitive aging.

Notes

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