Aware Technologies for Aging in Place: Understanding User Needs and Attitudes

The Aware Home Research Initiative hopes to help older adults "age in place" by creating devices that can assist with daily tasks, offer memory support, and monitor daily activities. However, understanding user needs and attitudes is essential to deploying this technology.

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Although computing technology has made inroads into home environments, it has yet to instigate a major shift in the design of homes or home activities. The convergence of television and the Internet is lagging behind expectations, and the combination of desktop computers, entertainment consoles, televisions, and cell phones has yet to form a cohesive whole. One possible reason for this lag in progress is that these technologies don't address a coherent need—they merely augment current entertainment and communication practices.

We base our research on the premise that the next revolution of technology in the home will arise from devices that help older adults maintain their independence. A coherent suite of technologies will eventually let older adults be proactive about their own healthcare, will aid them in daily activities and help them learn new skills, will create new avenues for social communication, and will help ensure their safety and well being. More important, these computational technologies will let adults *age in place*—that is, remain in their own homes for as long as they can care for themselves.[1,2]

The Aware Home Research Initiative at the Georgia Institute of Technology is examining the design, development, and evaluation of many related technological possibilities, including

- *Compensating for physical decline*. Ironically, using technology is also a potential barrier for older adults, because controls are typically difficult to see, operate, and remember.
- *Aiding recall of past actions*. Memory capabilities decline with age, including the ability to recall recent actions. This deficit hinders older adults from completing tasks when interrupted or distracted.
- *Supporting awareness for extended family members*. The challenge of aging in place extends past the confines of an older adult's home. Family members—typically adult children—must maintain a sufficient awareness of their parents' well being.

Our research examines the usability and engineering challenges in designing devices for aging in place. More importantly, it also assesses the likelihood that older adults will adopt and use these technologies in their daily lives.

Technologies to support aging in place

From a societal perspective, it's cost-effective to support older adults' preference to age in place. Data from a study in the UK, for example, suggests that private residential living costs

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Figure 1. The Georgia Tech Broadband Residential Laboratory, otherwise known as the Aware Home. This unique laboratory, located on the edge of campus, supports technology development and evaluation.

only 55 percent of the costs of full-time residential care.[3]

However, numerous challenges to aging in place exist, only some of which are being addressed by industrial and medical products. The most obvious needs are medical alerts for an emergency response following a fall or medical crisis, but substantial needs exist beyond preventing or responding to a crisis.

Preconditions for autonomy and independence in everyday life are the independent performance of basic activities of daily living (ADLs), such as eating, bathing, and dressing, and instrumental activities of daily living (IADLs), such as cooking healthy meals, adequately dealing with medication, and doing laundry.[4] Losing everyday independence is a major concern of currently healthy, older adults living independently,[5] because it could lead to an involuntary move to an assisted-living facility or a nursing home.[1,2] Such concerns are directly related to the performance of ADLs and IADLs.

Our research addresses physical and cognitive needs in support of daily activities and communication supports for social connection and awareness. We're conducting our research at Georgia Tech's Broadband Institute Residential Laboratory, also called the Aware Home (see Figure 1). It has all the functional and design requirements of a normal home as well as facilities for instrumenting each room with sensors and displays to support ubiquitous interactions between the residents and the house.

The Gesture Pendant

The Gesture Pendant is a wireless device that lets a smart home's residents give commands in the form of hand movements (see Figure 2). For example, different gestures would close the blinds, lock the doors, open the front door, dim the lights, or raise the thermostat temperature. Worn around the neck, the Gesture Pendant has both a camera and motion sensors. It can take commands as well as monitor its user's physical activities and request help in an emergency. A potential side benefit is that it can track tremors in the hand, possibly serving as an early indicator of neurological impairments such as Parkinson's disease.[6]

Figure 2. The Gesture Pendant. This wearable computer recognizes a simple set of hand gestures using infrared illumination and a CCD (charge-coupled device) camera.

Cook's Collage

Memory impairments affect an individual's ability to perform—and in particular, to complete—common household tasks.[7] Many daily activities rely on these memory processes, and the consequences of age-related declines might be exacerbated if the older individual is distracted or interrupted. Simple examples include remembering whether you added detergent to the laundry, turned on the bathtub water, or added certain ingredients to the dinner you're preparing. Younger adults might also experience memory problems when distracted, interrupted, or faced with competing demands for attention.

A strategy for minimizing impairments in performance owing to memory deficits is to provide records of recent actions that serve as a surrogate memory and let an individual resume an interrupted task.[8] This recording function is a reasonable task for computational support, because computers can visually capture a series of events and select key frames to depict those events without needing to understand the events or provide prospective memory support by identifying likely goals.

Figure 3. Cook's Collage. Cameras mounted underneath cabinets capture still images of cooking activity. Images are time-ordered, and the numbers in the upper left indicate repeated actions, such as adding multiple cups of flour.

We opted to explore memory lapses during a common household task—cooking. This is a physical activity subject to distractions and interruptions. Mistakes are costly but mostly not life-threatening. The process consists of specific activities (for example, adding a cup of flour), but rote cooking from a recipe isn't the norm. So, a predictive system (such as "next, do this") could often be wrong, but a capture system ("here's what you've been doing") could help a user remember specific actions.

Our prototype system—Cook's Collage—provides surrogate memory support for general cooking tasks. The current design emphasizes the temporal order of cooking events and arranges visual snapshots as a series of panels, similar to a comic strip, on a flat-panel display mounted on a kitchen cabinet. 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 the content, such as faces, that often exacerbates privacy concerns and general discomfort with visual sensing. Figure 3 shows six images in order, with the upper left being the oldest and the lower right being the most recent (the numbers indicate repeated actions).

We currently simulate the system's object-and-action recognition by having a human operator select images in real time as a person cooks. This "Wizard of Oz" simulation technique lets us understand the task demands and usability barriers for this service before investing in developing the system's computational-perception infrastructure for recognizing common cooking actions.

Digital Family Portrait

We must frequently balance older adults' desire to remain in the familiar setting of their own homes with their extended families' desires to keep them safe. Clearly, this balance becomes more precarious as age increases. Geographic distance between extended family members exacerbates the problem by denying the casual daily contact that naturally occurs when families are colocated.[9]

The Digital Family Portrait is an in-home monitoring system that informs family members about an older relative's daily activities, health status, and potential problems. It also offers information about patterns of activities over a certain time period. 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. Various sensing technologies (such as radio-frequency-badge tracking and computer vision) can gather information about the individual pictured on the display and integrate it into the interface. The current design presents iconic imagery summarizing four weeks of daily household life.

Figure 4a shows the Digital Family Portrait's default display, which illustrates the relative activity levels of the older woman pictured. Each butterfly depicts one day of information. We designed the portrait so that users can continuously display it in their home and interpret it with minimal effort. By touching the butterfly for a particular day, the viewer can see more details about that day and the individual. The detail screen (see Figure 4b) includes information about the weather as well as 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's raining outside.

This portrait measures the woman's activity on the basis of her movements in her home using motion sensors. Although many details are available, viewers can also quickly read the visualization, for example noting numerous trips to the bathroom during the night or perusing the daily activities' overall flow.

Assessment by older adults

Greg Sarkisian, Anne-Sophie Melenhorst, Arthur Fisk, and Wendy Rogers' study of older adults' perception of Georgia Tech's Aware Home reveals opinions, considerations, and ideas about intro-

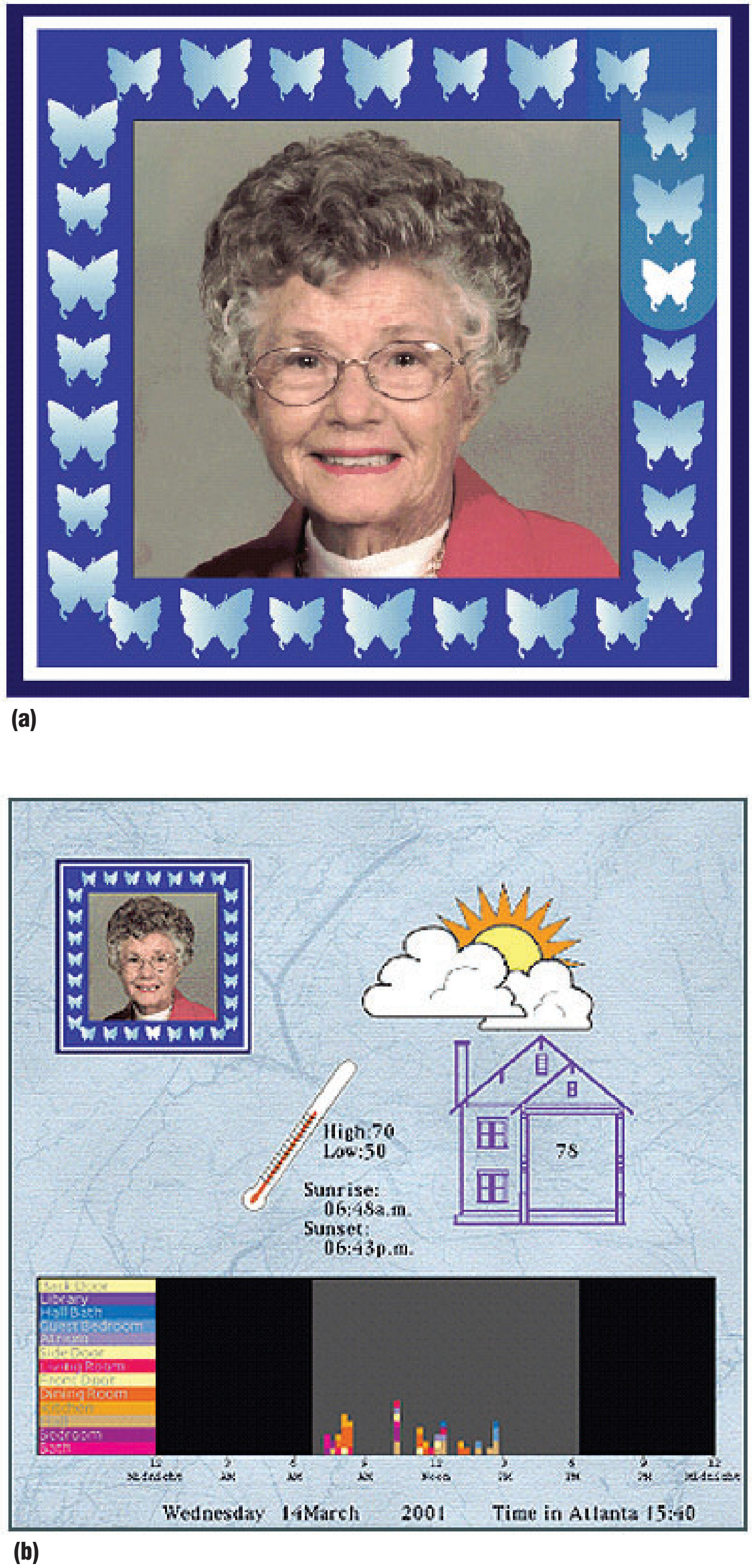

Figure 4. The Digital Family Portrait: (a) The day's average activity is categorized into one of four levels and indicated by the size of the butterfly icons. The current day is in white, and time progresses clockwise around the picture. (b) Touching a butterfly icon brings up the detail display for that day, including weather conditions and outdoor and indoor temperatures. Movement between rooms is shown in 15-minute increments. Background shading indicates day or night.

ducing newly developing technology in the home as it might become available in the coming decades.[10] The researchers took 44 participants aged 65 to 75 (15 men and 29 women), currently living independently, on an individual tour of the Aware Home. During the tour, they presented the participants with five selected smart-home devices—including the three discussed here.

After the tour, the researchers performed structured interviews, which were transcribed verbatim and which yielded 2,136 quotes. Each quote expresses an opinion or value judgment about the devices shown during the tour or about living in a technology-rich home environment. The researchers categorized the selected quotes according to a coding scheme that used a set of relevant criteria that abstractly addressed the quotes' contents. The scheme included a category for judgment, with subcategories such as "positive" or "negative." It also distinguished conditional value judgments, such as "I don't like it if it invades my privacy." Another main category captured the participant's motivation for the judgment, listing technology issues and concerns (for example, privacy, independence, autonomy, necessity, and convenience). The researchers determined the main categories beforehand (top down), focusing on the study's goal: gaining insight into the participants' perception of a technology-rich home environment. The subcategories were also developed bottom-up, on the basis of the data's details.

The tension between assistance and autonomy

The study participants were relatively healthy, so most viewed the Gesture Pendant as something they wouldn't need for several years. To them, using it indicated a physical dependence and loss of autonomy. The participants were viewing the new technology in terms of necessity and need fulfillment related to disability rather than as a possible standard convenience in all future homes. For example, one participant said, "I'd rather do it myself … because I'm an independent person. Right now, I would have limited use for it—it would be a play toy, a time saver, an energy saver, to a degree."

This comment also illustrates concerns of overreliance on technology. Not using your competence can negatively affect your self-efficacy and independent everyday functioning.[11] Too much support—for example, in nursing homes—might lead to a loss of autonomy or even a decline in capability.[12] Some participants expected similar results from extended use of assistive technology in the home.

Other participants focused on the choice the technology allowed: "I can see how this would be a fantastic thing. And it should not make you feel any less independent. … It wouldn't make you feel like 'hey, they are tying me here.' It would afford you some sense of individuality—you have a choice, in other words."

Views of the Gesture Pendant reflect a general discussion in the field of gerontechnology about positive and negative effects of supportive technology in the home.[13,14] Technology can both increase and limit a person's feeling of independence. Older adults often view traditional technology in the home (such as a washing machine or remote control) as advantageous—they don't view it as stigmatizing. Like traditional appliances, the Gesture Pendant wasn't exclusively developed for older users, although they might benefit from it most. It could be both a convenience for everyone and, at some point, a necessary support for those who develop physical impairments as they age, helping them control their home environment.

The tension between privacy and independence

Comments about the Digital Family Portrait were more often a conditional statement, unlike comments about other devices. The preconditions of accepting the device could be classified in terms of

- *Who was monitoring them?* Constraining monitoring to a small set of family members, say one or two, was acceptable. Beyond that, privacy concerns increased.
- *Was it necessary?* They were open to the idea when they needed the device, but not before.
- *What was the optimal level of intrusion?* They didn't want people to know more than was necessary to maintain their independence. Additionally, they favored this approach to having someone with them all the time.

Unlike the Digital Family Portrait, Cook's Collage hardly evoked any privacy concerns, even though it uses cameras to track cooking actions. The lack of perceived intrusiveness seemed attributable to the task with which it's associated, to the limited scope of its potential intrusion due to the cameras' positions, and to the fact that the information isn't permanently stored. An additional advantage that several participants mentioned was that using Cook's Collage is optional, which seemed to influence their experience of intrusiveness. The low perceived cost and intrusion of Cook's Collage offers hope that similar systems could aid older adults in a host of memory-intensive tasks such as keeping track of medications and performing household chores, and multitasking in general.

Of course, a system such as Cook's Collage and the Digital Family Portrait are quite different. The first temporarily displays a relatively brief record of specific activity and typically shows that information to the same person. The other stores a month's worth of data about general household activity and transmits that information to someone outside the home. Unfortunately, the media and general public might still lump both types of applications together as representing "Big Brother" privacy concerns. Notably, neither system was summarily rejected by older adults, although their perceived value and costs varied considerably. Services such as the Digital Family Portrait could address the information needs of concerned family members. Unmet, these needs could result in the insistence that an older parent move to an institutional setting even when it's not logically needed. Balancing information needs and privacy within a family's social dynamics is indeed challenging.

Adequately addressing the Aware Home Research Initiative's challenges requires an interdisciplinary approach that spans technology and social concerns—bringing together engineering, computer science, psychology, and sociology. There are no simple answers or obvious solutions. By working directly with older adults and applying a top-down perspective from gerontology, we can better understand the intriguing trade-offs and tensions facing older adults as they contemplate using these technologies. They might accept a technology with significant privacy implications given its overall value for sustaining a more independent lifestyle. However, they might reject a simple technological aid owing to concerns of overreliance on technology.

Along this vein of research, we'll be conducting hands-on evaluations of these technologies with older adults. Specifically, we'll invite older adults to use our Cook's Collage under a variety of distracting situations. Initial results with younger cooks (college students) indicate that Cook's Collage is useful, although the cook must be self-aware about his or her own memory lapses, because the system doesn't intervene or set off an alarm when the user makes a mistake. We're also deploying a version of the Digital Family Portrait for a family near Georgia Tech: an older woman and her adult son. This field trial will help us understand the use of the portrait in the context of everyday life.

Many additional opportunities for these kinds of computational interventions exist. We're working on a system that helps older adults use new home healthcare devices such as a blood glucose monitor. We're also working on a prospective memory aid that helps older adults remember to perform tasks. ■

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