Statement by

Dr. Gregory D. Abowd

Associate Professor, College of Computing and GVU Center
Director, Aware Home Research Initiative
Georgia Institute of Technology

The Role of Technology for an Aging Population

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Mr. Chairman, Committee Members, and staff: I am Gregory Abowd, Associate Professor in the College of Computing and Director of the Aware Home Research Initiative at the Georgia Institute of Technology. I am thankful for this opportunity to testify today concerning how this country can meet the needs of an increasing aged population. My message today is a rather simple one, and that is we should look for ways in which technology can promote healthy and independent aging. We should more aggressively provide opportunities for scientific, engineering, government and commercial organizations to collaborate on large-scale efforts that provably meet the needs of the individuals, their families, their caregivers and the social and medical institutions that provide services to older adults.

The problems of our aging society are real, both in economic and social terms, and I believe many people in key positions understand this. The role of technology in enhancing the lives of older but otherwise healthy Americans is not well understood or appreciated. I will try to demonstrate some of the possibilities for technology that are being explored in research environments today. If these technologies were widely available, it would mean that older adults would be able to live more safely, independently and maintain a quality of life that they enjoyed in their younger years. While we all probably aspire to live long lives, we also hope to live healthy lives that don't cause undue burden to others. Realizing this goal will take investment in research, student training, and strategic partnerships with industry and government.

Background

I am a computer scientist working in the area of Human-Computer Interaction, the relationship between people and the computing artifacts they use. My particular area of interest is in an area called "ubiquitous computing," a term used to mean the proliferation of computing artifacts throughout our environment in support of our everyday activities in those environments. The vision of ubiquitous computing was first espoused by the late Mark Weiser, then working at the Xerox Palo Alto Research Center (PARC). Though the technological challenges of a world of constantly available and pervasive computing services are great, the motivation to work in this area is largely the human-centered agenda of providing assistance in our everyday lives.

Over the past five years, together with several colleagues at Georgia Tech and with the financial support from the State of Georgia through the Georgia Research Alliance, the National Science Foundation and several major computing companies (Motorola, Intel and Hewlett-Packard), we have been exploring the implications of ubiquitous computing technologies in the home. We refer to our efforts under the title of the Aware Home Research Initiative (http://www.awarehome.gatech.edu) because we believe that there are many intellectual challenges in creating a home environment that is made automatically aware of the whereabouts and activities of its occupants and can provide relevant services to inhabitants of that home as a result. A major motivation for this work is that awareness technologies can provide the assistance needed for otherwise healthy individuals to cope with the natural declines related to aging while staying in their own homes. Many refer to this goal as "aging in place." The reason I am speaking to you today is because many people believe that the type of research we are conducting in the Aware Home Research Initiative at Georgia Tech is promising. While I and my colleagues are flattered by that assessment, we deeply believe that significantly more large-scale efforts are needed to really make an impact with technology for the general problem of aging in place.

The Problem

There are several ways we can understand the challenges of an aging population. First is to see the problem as an issue of the cost of healthcare. Second, we can consider the social issue that underpins why people desire to "age in place." Third, we should understand the continuum of living environments in which aging individuals reside. We describe each of these issues more fully below.

Healthcare costs: The U.S. healthcare system is under severe stress and the situation will deteriorate rapidly after 2010, when the first wave of baby boomers reaches retirement age. The Congressional Budget Office states that "the financing problems in the near term will be dwarfed by the crisis that could occur as the baby-boom generation reaches age 65." (Antos, 1997) While the U.S. is the leader in healthcare expenditures, with more than 14% of the GDP devoted to healthcare and yearly increases of 1/3% (Smith *et al.*, 1997; Levit *et al.*, 2002)), it ranks only 37th in overall healthcare system performance (WHO, 2000). Reflecting dissatisfaction with the present healthcare system, US consumers spent $27 billion on health improvement and maintenance outside the established health care system in 1997 (Eisenberg *et al.*, 1998). Soon, the impact of the aging baby-boomer population will be felt: in 2030, nearly 1 out of 2 households will include someone who needs help performing basic activities of daily living (RW Johnson Foundation, 1996) and labor-intensive interventions will become impractical because of personnel shortage and cost. . Much has been written about this baby-boomer cohort, and it has been noted that compared with today's seniors, the boomer vanguard is better educated and more technologically adept. Thus, this cohort of people, as they age, may increasingly look to technology to help them maintain their health and independence, and to optimize their living environments.

Social costs: Across our lifespan, our living environment, or home, takes on great personal meaning. This meaning may reflect the attainment, or lack thereof, of any of a number of different dimensions, including status and achievement (e.g., home ownership), responsibility (e.g., maintaining a family home), security (e.g., safety), autonomy and privacy (e.g., personal choice and freedom). These different aspects of housing may take on different salience throughout an individual's lifespan. At the end of life, independence, autonomy, and safety are especially relevant. Older adults strive to maintain their independence and autonomy in a safe living environment. In addition to personal meaning, living environments have societal and political relevance as well. These include issues of affordability, adequacy, accessibility, and appropriateness of housing (Maddox, 2001). Thus, living environments are a critical issue for elderly adults, and for our society, as America ages. Repeated surveys from the American Association of Retired Persons (AARP) reflect the strong desire by older adults to remain in their own homes.

Where do older adults live? There are three main types of living environments for aging adults: independent living (e.g., private housing), assisted living, and nursing homes. According to the 2000 U.S. Census, approximately 95% of adults aged 65 and older reside in private households (Cohen & Miller, 2000). Given the preference of elderly adults to "age in place," private homes will remain an important housing option in the future, particularly for the young-old (under 85), and will be important targets for increased technology to help elders remain there.

Assisted living housing provides an option for older adults lacking complete functional independence to live independently for as long as possible, in communities designed to provide the security of having reliable services available for use as needed (Maddox, 2001). The consumer demand for housing that is private, provides needed services, is "non-institutional," and provides residents with choice and control has been very high. Private-sector developers have been responsive to consumer demand, and the number of assisted living facilities in the United States has grown dramatically. By 1998, there were at least 28,000 assisted living facilities in the US (Mollica, 1998). It has been estimated that as many as 1.5 million elderly adults currently reside in assisted living housing (U.S. General Accounting Office, 1999) and this trend is expected to continue.

Prior to the development of assisted living housing, nursing homes were the only option for elderly adults who needed health care services that could not be provided at home. In contrast to assisted living facilities, nursing homes are a more medical environment, characterized by minimal personal autonomy and maximal dependence on formal caregivers. Uniformed nursing

assistants provide 80-90% of all direct care in this setting. Nursing homes were considered to be a long-term care facility; that is, elderly adults who were too physically frail, too cognitively impaired, or too socially isolated to remain at home moved into a nursing home, and most lived there until death. Admission to a nursing home was often feared and avoided for many reasons, including the connotation of these facilities as "the last stop" before death, the poor quality of care provided in them, and the lack of autonomy and privacy. Since 1986, improvements motivated by the Institute on Medicine have removed some of the stigma of skilled nursing. Currently, there are approximately 17,000 nursing homes in the United States, providing care for over 1.6 million elders (U.S. GAO, 1999). Whether or not one lives in a nursing home is highly age-related, with almost half of all residents falling in the age 85 and over category (U.S. GAO, 1999).

Independent living, assisted living housing, and nursing homes are often viewed on a continuum. The most healthy, most independent elders live at home; the most frail, most dependent elders live in nursing homes. Indeed, over the past decade or so, continuing care retirement communities (CCRC) have been developed to capitalize on this continuum of care model.

One important kind of retirement community to consider, especially when we want to think about technological assistance, are naturally occurring retirement communities (NORCs), defined by the AARP as a "building or neighborhood where more than 50% of the residents are over 60." NORCs have been recognized as an important kind of community since the 1980's and in 1992 AARP estimated that 27% of older people lived in a NORC, largely due to the desire to age in place.

It is going to be easiest to explore the impact of technologies for healthy and independent aging in newly constructed CCRCs. Initially, the technology will be more expensive and it will be more cost-effective to build it into new construction. Baby boomers choosing to move into these new CCRCs will have the finances to pay for this, and in fact will expect these kinds of services to support their long-term health and independence. But the ultimate success in this area will depend on being able to retrofit lower-income NORCs with commodity technologies that also promote health and independence, providing families with peace of mind for aging parents and reducing the burden on the government and other institutions who would otherwise have to pay for the necessary care.

The Goal for Technology

What role can and should technology play for assisting an aging population? I would break this answer down into a couple of key categories:

- Providing assistance to the individual who wishes to maintain independence and quality of life.
- Providing support for distributed family members and other caregivers who share the financial and emotional burden of coping with the challenges of aging.
- Providing mechanisms for larger social/government institutions (medical, police, social workers) to provide their services more effectively without incurring unmanageable cost.
- Providing marketable services with profitable business plans that will encourage private investment and commercial success in this important market.

One of the key determinants for where one chooses to live is the level of independence that can be maintained by that individual in that environment. There are quantitative measures for determining independence, referred to as the various classes of Activities of Daily Living, or ADLs. Though I will not go into a detailed discussion of ADLs, it is important to note that researchers have tried to use performance on ADLs as a measure of independence. This suggests that a key goal for assistive technology is the extent to which it empowers an individual to

maintain adequate performance for these activities. It is also important to maintain strong social connections with natural support groups (e.g., family and friends) and encourage active physical and intellectual routines, proper diet and compliance with medication regimes.

Forms of Technological Assistance

I will review a variety of technologies that have been developed to support the independence and security of an aging population in a variety of living environments. The categories of technology we consider are:

- *assistive devices* that compensate for motor, sensory or cognitive difficulties;
- *monitor and response systems*, both for emergency response to crisis situations and for early warning for less critical and emerging problems; and
- *social communication aids*.

Assistive devices

As is well known, aging results in changes to many human capabilities (Mynatt & Rogers, 2002). Age-related changes in motor movement include slowing, inability to make continuous motions, and lack of or variable coordination (Vercruyssen, 1997). Sensory difficulties are also common, and much is known about changes in vision and audition (Schneider & Picora-Fuller, 2000, Schaie, 2003). For many years, devices that replace or compensate for deficiencies in motor and sensory capabilities have been readily available, and many of these are suitable for both the young and the old. Difficulties in gross motor movement are mitigated either by devices that perform the motor function, such as powered wheelchairs and stair climbers, or provide assistance, such as well-placed grab bars in bathrooms or power-assisted chairs that facilitate sitting and rising. Hearing aids and low-light visual cues are available to assist those declining senses. These physical deficiencies make it hard to operate a lot of the small appliances and controls that are commonplace in homes today. Researchers at places like the University of Florida's Rehabilitation Engineering Research Center on Technology for Successful Aging (http://www.rerc.ufl.edu/) evaluate the effectiveness of a variety of designs for adaptive household appliances and controls. At the Georgia Institute of Technology, computer vision researchers have prototyped the Gesture Pendant as a wearable device to control a variety of home appliances through simple hand gestures (Starner *et al.*, 2000).

More recently, the field of cognitive aging has matured and we better understand how changes in cognitive function occur as part of the natural process of aging (Craik & Salthouse, 2000; Schaie, 2003). Declines are apparent in attributes such as the capacity of working memory, online reasoning, and the ability to attend to more than one source of information. Other abilities remain largely intact, such as recall of rehearsed material, vocabulary and reading and ability to focus on a single source of information.

Technological support for cognitive aging, often referred to as *cognitive orthotics*, is a very promising direction for research, evidenced by a recent survey on assistive technology for cognition by LoPresti *et al*., (in press). The applications of cognitive orthotics range from simple reminder systems to more elaborate interactive robotic assistants.

LoPresti *et al.* provide a useful categorization of cognitive orthotics along two separate dimensions. The technological interventions are first distinguished by whether they support executive function or information processing. Executive functions include planning, task sequencing and prioritization, self-monitoring, problem solving and self-initiation and adaptability. These executive skills are related to memory, attention and orientation. Information processing concerns the ability of the brain to properly process and integrate sensory information, with deficiencies leading to problems in the processing of visual-spatial, auditory, sensory-motor and language information, as well as difficulties in understanding social cues. The second

dimension for technological aids concerns whether they attempt to strengthen a person's intrinsic abilities or seek to provide extrinsic support. Intrinsic aids are often classified as rehabilitation technologies, while extrinsic aids are considered as compensation technologies. I emphasize the extrinsic, or compensation technologies, to address issues of support for aging of otherwise healthy individuals. This whole area of cognitive orthotics is of growing interest. For example, the reader is referred to the results of a 2002 workshop on cognitive aids from within the Computer Science community (see http://www.cs.washington.edu/homes/kautz/ubicog/). Also, Jorge *et al.* (2001) reports on a recent workshop relating ubiquitous computing and universal access in providing for the elderly. The National Science Foundation will co-sponsor an international workshop on the theme of technologies for aging in June 2003 in London.

Some cognitive orthotics work focuses on support for extreme cognitive dysfunction, such as Alzheimer's disease or severe dementia. For example, within the Gloucester Smart House consortium (http://www.bath.ac.uk/bime/projects/smart/) devices such as a locator for lost possessions are designed to be usable by people with dementia and their caretakers in order to prolong independent living. Mihailidis *et al.* (2000) conducted a pilot study, and observed that a person with severe dementia would complete an activity of daily living in response to a computerized device that used a recorded voice for cueing. The computerized device monitored and prompted a subject through hand washing. In response to problems discovered with their first prototype, Mihailidis *et al.* (2001) used artificial intelligence to develop a new cognitive orthotic for people with moderate-to-severe dementia.

There is also work that aims to design systems for people in the less severe stages of memory impairment. Many people have difficulty locating important objects around the home, and commercial versions of the Gloucester Smart House object location system are available at high-end consumer outlets like The Sharper Image. These solutions work for a small number of specialized objects, like keys. One of the research efforts at the University of Rochester's Center for Future Health (http://www.futurehealth.rochester.edu) involves computer vision researchers trying to develop more flexible object tracking systems to assist with the location of a wider variety of lost objects within the home. The Nursebot project at Carnegie Mellon University, University of Pittsburgh and University of Michigan (http://www-2.cs.cmu.edu/~nursebot/) has been investigating ways that a robotic assistant, Pearl, can assist in eldercare (Montemerlo *et al.* 2002). One of the cognitive aids being developed uses a system called Autominder, developed by Pollack and colleagues at Michigan, to remind an older person about his or her activities of daily living (Pollack *et al.*, 2003). Several commercial products provide support for prospective memory aids. Within the Aware Home Research Initiative at the Georgia Institute of Technology (http://www.awarehome.gatech.edu), researchers are focusing on short-term retrospective memory. Mynatt and Rogers (2002) proposed initial designs for a visual collage to assist one to resume routine cooking tasks after an interruption. This simulated memory aid records and displays salient near-term actions from a recipe so that, upon resumption from an interruption, the cook can determine things like how many cups of flour have already been added to the mixing bowl.

Many cognitive orthotics are designed to support prospective memory, that is, remembering tasks that need to be performed and carrying out these tasks at the appropriate time (Ellis, 1996). This work has progressed from using very basic and inexpensive timing technologies (e.g., calendars, timers and watches) to much more sophisticated and forward-thinking applications of artificial intelligence. One of the most important examples of prospective memory tasks is medication compliance. Medication compliance devices range from plastic boxes divided into sections labeled by times and day, to electronic systems that provide auditory cues (Fernie & Fernie, 1996). For an individual living alone, remembering to take medication at the right time and in the right order can make the difference between remaining independent or not.

Monitor and response systems

We have all seen the classic "I've fallen and I can't get up!" commercials. This caricature is sometimes humorous, but it is representative of an important class of technology that provides monitoring of health and well-being status, communication to interested parties, and in some cases provides automated responses to perform some corrective action. These monitor/response systems can operate in the short-term to sense a crisis situation, such as a fall, and provide a way to make a call for help. Medical alert systems (e.g., LifeFone, http://www.lifefone.com/) allow a greater degree of freedom for an older person, and peace of mind for adult children, by allowing independence while providing a safety net in case of medical crisis. Some devices might automatically detect a crisis (such as a fall). Others depend on activation by the individual (or someone nearby) to initiate a call for help. Monitoring systems are characterized by:

- What information is being recorded or transmitted? It could be medical information (e.g., heart rate, respiration, blood pressure, medication compliance, incontinence), movement data (e.g., restlessness in bed, gait patterns), or simply awareness information (e.g., a video transmission to a relative).
- Over what period of time is data analyzed? The capture of information can be for instantaneous purposes only (e.g., a "GrannyCam" usually transmits images over the Internet to be viewed in real-time only) or over a period of time for trend analysis, as you would expect for vital signs in a telemedicine application or in medication monitoring for compliance in a home or assisted living environment.
- How is information reported to relevant individuals? Medical alert systems provide a phone call to a response agency. Telemedicine applications report over a secure channel to an electronic patient record that can be consulted by trusted medical professionals or even by the individual being monitored. Cameras are used to provide easy monitoring for family (usually over the Internet, serving an important social communication function discussed below) or remote caregivers (at a nursing station, for example).
- What is the role of the elderly person in using the technology? Does the monitoring require any instrumentation or active cooperation on the part of the individual being monitored? For example, do they have to wear an infrared badge for a positioning system, or is it passive,with the environment instrumented to measure a naturally-occurring phenomenon using devices such as a motion detector or face recognition system?

There are many examples of these monitoring systems for an aging population. Some address the safety and security of individuals who may wander. Devices can either prevent undesired wandering (e.g., automatically closing doors or gates to a house or community grounds to protect Alzheimer's patients) or remind others to take corrective action (e.g., at nighttime when someone inappropriately leaves the bed). A system like the Vigil Integrated Care Management System™ (http://www.vigil-inc.com/), which can detect cases of incontinence via special moisture sensors on bedsheets, allows staff to schedule pre-emptive nighttime wakings to prevent accidents in the future. Simple load sensors in the beds of residents at Elite Care's Oatfield Estates Cluster in Milwaukie, Oregon (http://www.elite-care.com) feed a visualization to allow caretakers to detect periods of restlessness in the night. Some of the more advanced research in this area is trying to use passive means to perform early detection of chronic, but treatable conditions. For example, researchers at the University of Rochester's Center for Future Health (http://www.futurehealth.rochester.edu/) are using computer vision techniques to determine asymmetries in gait patterns during visits to the doctor. These data can provide early warning of the possible onset of a wide range of common neurological and musculoskeletal disorders such as stroke, Parkinson's disease and arthritis. Similarly, the same vision technology that underlies the Gesture Pendant (Starner *et al.*, 2000) can detect asymmetric tremors indicative of Parkinson's

disease and can be used to track the effectiveness of medication regimes to control the disease. Though the monitoring technology is not used in these cases to treat the condition of an individual, early detection can increase the effectiveness of medical intervention and counseling for the afflicted. But with most of these research projects, the technology is unproven and significant challenges remain to make them viable.

Cognitive orthotics discussed earlier rely on context-sensitive reminders, and these often require a way to monitor a person's environment and activities (LoPresti *et al.*, in press). Some research is focused on monitoring ADL tasks in the home using a variety of sensing technologies. Sensors and switches attached to various objects, or optical and audio sensors embedded in the environment, are used to detect which task a person is performing. Trials with several subjects indicate that this method of tracking a person's actions is a good way to monitor the state of a person's health and independence (Bai *et al.*, 2000; Nambu *et al.*, 2000). Friedman (1993) developed a wearable microcomputer with a location-sensing system and additional sensors to determine task-related information. Using these inputs, together with the user's schedule, the computer provided voice prompts as needed and only as needed to help the user maintain his or her schedule. Continued evidence of difficulty adhering to the schedule would cause the computer to automatically call for human assistance (Friedman, 1993). By only providing prompts as needed, the system could "fade" (gradually reduce) cues and therefore decrease the user's dependence on them. Because the system does not rely solely on a timed schedule to determine the user's possible activities, it could allow more user independence.

Social communication aids

The social aspects of aging, are also an important part of the equation in determining the health, safety, functioning, and autonomy of elderly adults, Peace of mind is an important element for the individual and a distributed family (Mynatt & Rogers, 2002). Geographic distance between extended family members exacerbates the problem by denying the casual daily contact that naturally occurs when families are co-located" (Mynatt, *et al.*, 2001).

Technology can connect individuals with information. Over the past decade, the burgeoning Internet has introduced a wealth of health information to many who would otherwise not have access to it. More relevant to this chapter, technology can connect individuals with other individuals or groups. Synchronous forms of communication, such as videophones or "smart intercoms" (Nagel *et al.,* 2001), present compelling visions of seamless communication aids, but have not experienced any substantial use. Asynchronous forms of communication, such as electronic mail, newsgroups and online forums (e.g., SeniorNet http://www.seniornet.org/php/) are all examples of communication technologies that have hit the mainstream. When seniors see clear benefits of communication technologies, acceptance is likely (Melenhorst *et al.*, 2001) and there is evidence that they are willing and capable of learning new skills.

Mynatt and colleagues (2001) suggest a particularly novel asynchronous communication aid as part of the Aware Home Research Initiative. A digital family portrait is an electronic equivalent of the picture of a loved one that we often find in our own homes. However, the digital family portrait is also used to portray a qualitative and dynamic account of the well being of the subject by means of icons embedded in the frame of the picture. Monitoring systems in the home of the subject are used to provide summaries of the daily life. The digital family portrait shows a history of one month's activity, providing an aesthetically acceptable communication aid aimed directly at supporting awareness for a distant adult child. This use of technology is trying to approximate the subtle peace of mind that comes from physical proximity.

Conclusions

I would like to conclude this statement with a few important points. Aging is not a disease; today, we better understand the physical, sensory and cognitive impact of the aging process. Ultimately,

a healthy older population is economically favorable, and technology can assist in promoting health and independence. However, there have not been sufficient explorations to date to demonstrate and measure the impact of technology on healthy aging. Though I have surveyed a lot of potential technological aids, I must stress that there remains significant advances in technologies of sensing and long-term analysis of human behaviors that will not occur unless sufficient funding is made available. What is needed at this time is investment in large-scale test beds for exploring technology for healthy aging. The challenge of technological support for healthy aging is not entirely the government's responsibility. However, without sufficient quantitative evidence of the economic impact of these technologies, few business plans will be developed to commercialize these technologies and insurance companies will have little to base financial incentives that would encourage private investment in these technologies. While it ultimately will not be the (local, state or national) government's responsibility to finance the use of technology for healthy aging, proactive and aggressive government initiatives are necessary to bootstrap the process. Research organizations that fund technology research, such as the National Science Foundation, must make technology for healthy aging part of their charter. Organizations that promote preventive healthcare or combating health deterioration, such as the National Institutes on Health, Health and Human Services, and the Department of Education, must modify their charters to encourage the development of newer technologies. These investments will increase the likelihood that research activities larger than the Aware Home Research Initiative will contribute to this country's need to support the long-term health of its aging population.

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