

Inventing Wellness Systems for Aging in Place

BY ERIC DISHMAN

In 1999, I led a team of Intel social scientists in an anthropological study of 100 households in the U.S. and Europe that had been early adopters of broadband technology. One of the participants in this study was Sheila, a schoolteacher who had been the first person on her block to get high-speed Internet access because she wanted to videoconference with her granddaughter, who lived three time zones away.

Even while complaining of the “hideous Ethernet cables” snaking around her living room and the recurrent need to reset the modem, Sheila also described the technology as “nothing less than a miracle for the relationship it has given me with my granddaughter.”

Having already given up her much-loved career to care for her own ailing mother, Sheila now faced becoming a caregiver for her husband’s mother as well.

She was asking for another technological miracle:

What we really need is something to help us look in on my mother-in-law, who lives alone in upstate New York. She has early-stage Alzheimer’s, and the closest person who can help her is Tom’s sister who lives five hours away. Surely we’re not the only ones needing help helping our parents!

Sheila’s pleas for help in caring for aging parents were shared by almost every person in our study over age 40. As a result, in April 2002, I proposed Proactive Health (www.intel.com/research/prohealth/), a small lab that is

exploring the ways technology might assist with the care of a growing elderly population. Our mission is to catalyze a research ecosystem around information technologies that can help people be more proactive about managing health-related activities.

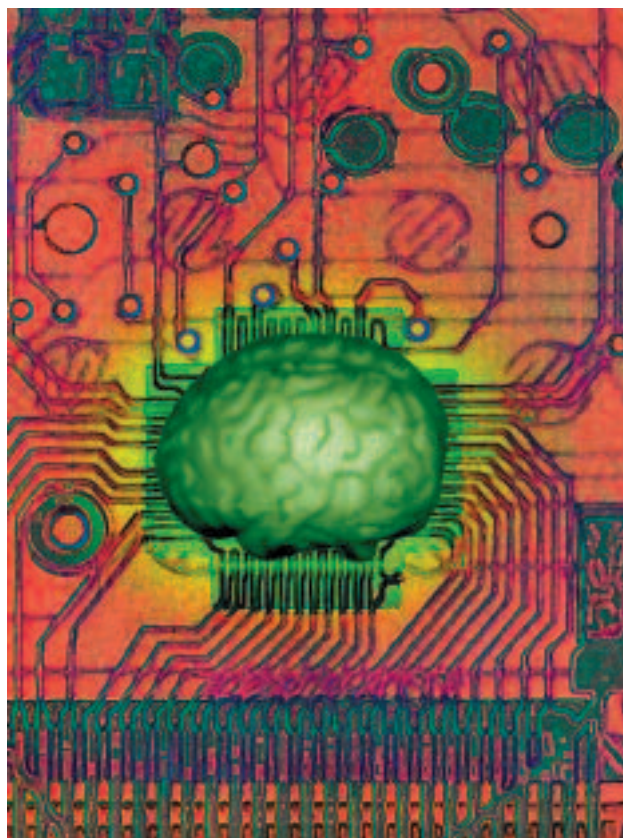
The lab focuses on households dealing with three particular conditions that have enormous impact on seniors’ lives: cognitive decline, cancer, and cardiovascular disease. These conditions provide a diverse and sometimes extreme set of research challenges to guide the development of “aging in place” technologies. In addition to improving the quality of life for seniors and their caregivers, these technologies could also reduce the increasing costs of clinic- and disease-oriented approaches to care. [Editor’s Note: Intel’s Proactive Health research has since expanded to include technologies to support health and wellness,

including physical fitness applications.] Ultimately, aging-in-place research supports a broader vision of “personal wellness systems” that provide highly individualized support for home-based health care to all age groups.

An Aging Population Worldwide

[Health care] is the largest segment of the economy in the U.S., and ... it is becoming too expensive to deliver. We’re still living in the “mainframe” era of health care... [W]e can’t, as a society, afford to devote any more of our economy to it ... [W]hat we need is ... the health care equivalent of the low-cost PC.

—Andy Grove, Fortune interview¹



The U.S. Congress, already facing an annual health care bill of more than \$1.5 trillion, is struggling to provide prescription drug benefits for the elderly and shore up the Social Security system that supplements their income. And it's less than 10 years before the first "baby boomers" reach retirement age, ushering in an era when the elderly population is for the first time expected to outnumber the young.²

Exhibit 1 shows the U.S. population growth for three different age groups from 1975 to 2025. The overall population increase over this period is about 60 percent, from almost 216 million in 1975 to close to 350 million projected in 2025. However, the percentage of the population under age 65 declines, and the percentage age 65 and older increases from 10.6 in 1975 to 18.2 in 2025.

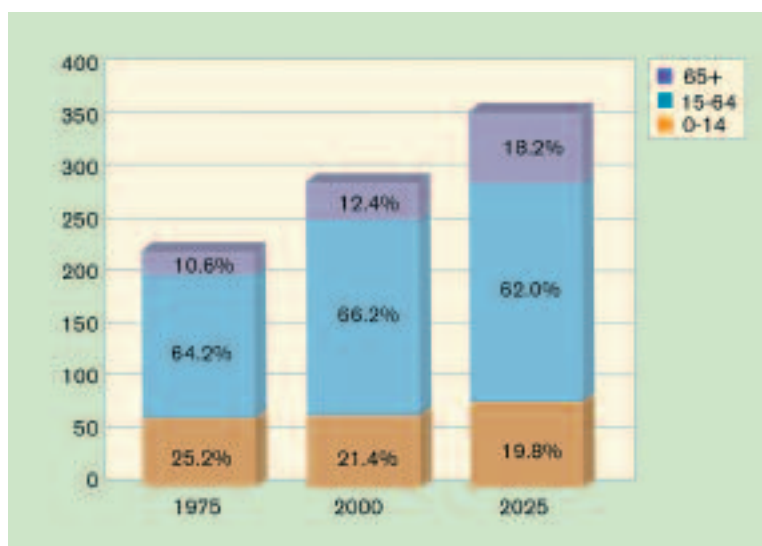


Exhibit 1. U.S. population growth of three age groups for 1975 and 2000 and projected for 2025. The elderly segment is increasing almost twice as fast as the rest of the population. (Source: U.S. Census Bureau)

This trend is global. The worldwide population over age 65 is expected to more than double from 357 million in 1990 to 761 million by 2025.³ Older adults already constitute one-fifth of the total population of much of Western Europe and Japan. In many countries, the ratio of workers to retirees will drop to 2:1, which will profoundly affect national economies and business productivity.

Meanwhile, longevity has given rise to expensive age-related disabilities and diseases, such as Alzheimer's. In addition to the standard medical treatment for these conditions, almost one-third of U.S. adults, most of whom also held full-time jobs, were serving as informal caregivers—mostly to an elderly parent.⁴

The cost of replacing this assistance to older Americans was estimated at a minimum of \$45 billion. Clearly, "business as usual" will not work for health care systems. We must

invent a different way of caring for a rapidly growing population of older adults—historically the most expensive demographic to treat—while reducing already unsustainable health care costs that plague virtually every major government.

From Mainframe Health Care to Personal Wellness

Health care's costs, coverage problems, and demographic pressures mean system overload; its formal institutions can't cope with the future. What will ease the pain? A major shift, enabled by technology, to self care, mobile care, home care.

—Forrester Research⁵

We already have an infrastructure for managing illness: a body of medical knowledge for classifying tissues and symptoms; an arsenal of pharmacological and medical technologies to help treat disease; and a clinic-oriented health care paradigm that is optimized for reacting to crisis. Now we must invent an infrastructure for maintaining wellness: a body of knowledge for holistic approaches to preventive care; an arsenal of personal technologies to help detect disease early and support compliance with commonly accepted care plans; and a consumer-oriented health care paradigm that is optimized for aging in place and informal caregiving.

Andy Grove's mainframe metaphor is apt. To move beyond mainframe health care, we must personalize and "consumerize" health and wellness technologies—pushing them into the home, where real-time prevention, diagnosis, and treatment can occur. Cost-saving transformations in

health care will only occur when we shift the locus of innovation from physician-operated systems at the health care mainframe to consumer-operated personal wellness systems deployed in homes, workplaces, even cars.

Telemedicine has begun this push with home-based videoconferencing and medical diagnostic technologies that support a "virtual exam." However, telemedicine alone cannot solve the crisis that an aging population poses because it perpetuates the formal health care system. It keeps expensive, overburdened doctors and nurses in the loop, and it focuses our investment and innovation on treating disease instead of preventing it.

Technologies for Aging in Place

How will personal wellness systems achieve real cost savings? Only carefully designed technology trials will tell for

sure, but we do know that the cost of care increases with increased levels of assistance. Helping seniors stay as independent as possible makes sense.

In 2003, the U.S. National Research Council sponsored the Technology for Adaptive Aging workshop to identify applications that could help older adults live healthier and more productive lives.⁶ Intel's Proactive Health research group is focusing on four promising areas:

1 Promoting Healthy Behaviors

Most macroeconomic analysis has shown that the key to simultaneously saving costs while maintaining quality health care is to foster more healthy behaviors in large segments of the population. Designing support systems that can help people change their everyday behaviors at home, work, and play—not just when they are at a medical clinic or prompted by illness or other medical emergency—can prevent many problems in the first place.

Not all of these problems are life threatening. For example, many nursing home admissions occur because of incontinence. A system that appropriately and discreetly reminds someone at risk to go to the bathroom before they have an episode could save the high costs of nursing home care and keep many seniors happily in their own homes for years longer.

Automatic data input is a primary technological challenge in the prevention domain. The questions that aging-in-place technologies must answer are a superset of the questions for digital home technology in general. How can we automatically capture data about people's daily activities? How can we visualize the data in meaningful ways? What architectures will people trust to collect data on their behalf?

What Technology Means for Alternate Site Infusion

This article points to two well-documented trends that will significantly impact the alternate infusion field over the next few years. Our population is aging. At the same time, a huge influx of “baby boomers” will turn 60 over the next five years, requiring more aging- and health-related services. These developments will create a demographic challenge unlike any seen before by our health care system—all while our nation faces a pressing need to reduce spiraling health care costs overall.

Not only will boomers require additional levels of care, they represent a generation that has high expectations of what can be delivered to them. We know that through exciting health care advancements and better awareness, people are living much longer. Many of these boomers will live into their 90s; turning 100 will no longer be a rare event. So, how can health care delivery meet their needs and expectations while cutting expenditures?

Experts have described this situation as the health care system's perfect storm. Large numbers of people needing care, expecting care over a much longer period in a health care system that is totally overwhelmed and trying to reduce costs. We know that many experts predict that the Medicare Trust Fund could be insolvent in the next 10 to 11 years. With almost 60 percent of every health care dollar in this country flowing through Medicare and Medicaid, this should be a wake up call that change is needed.

To further complicate the picture for infusion providers, we know now that there is a shortage of skilled nurses, and projections are that the shortage will become more severe over the next 10 years. What can we do to ensure that we can continue to provide quality care outside the formal institutional setting where it's more cost-effective?

We need to study what other segments of the health care community are doing to use developing digital technologies to monitor and support home-based care. The potential exists to use telehealth monitoring systems to track patient conditions and respond to any developing problems, use future health care information delivery systems that will come through the patient's own home cable or broadband systems, and give nurses tools to better track, monitor, and teach patients without having to make as many in-person visits. Think of a future where the infusion patient, family member, or caregiver can push a button on a TV remote and pull up a pharmacist or nurse to directly ask questions or seek guidance.

It's already possible; these technologies are operating in test centers around the world today. The trend towards more health care in the home is only going to escalate. We need to ride this wave—become more aware of developing technologies, make the innovators aware of how technology can assist our field, and adopt existing technologies that work—to help our patients as well as our businesses.



Software agents are another technology that can provide various kinds of assistance for home-based care, but its effectiveness depends on the right balance of “assistance” versus “nuisance” as well as appropriate interfaces, devices, and media.

Finally, we know that peer support is an effective tool for changing behavior. We need to determine what kinds of online support paradigms are effective for seniors and what technologies can help remote households check in on each other.

2 Early Disease Detection

As more biological and behavioral sensors find their way into the home, we have the opportunity to study the unfolding of disease processes in ways never before imagined. Mobile, embedded, wearable, and even implantable technologies can help to establish personal baselines—typical sleep patterns, eating habits, body temperature, and blood pressure.

Home-based sensor and diagnostic technologies could help establish “disease signatures” that show up physiologically and behaviorally before more severe symptoms become readily apparent. For example, sensor networks combined with an intelligent inference engine might someday not only detect dementia’s onset earlier but also perhaps analyze its type according to a complex calculus of the nature of memory loss, social behaviors, and changes in personal routines.

Research must address not only medical science and engineering issues but also questions of storing and analyzing data collected perhaps over decades. Trust and privacy also pose critical policy and technological challenges in this area.

3 Improved Treatment Compliance

Decades of pharmacological and physician research have led to the notion of “evidence-based medicine” and health care “best practices.” In other words, medical professionals have a pretty good idea of what courses of action will help people recover from thousands of diseases and injuries. Getting people to follow those courses of action is a different challenge.

Home-based systems that allow personalization and customization of everything from the device to the application and interface offer hope for improving human compliance with the care plans the medical community has studied and sanctioned. Some studies show that even slight improvements in people’s compliance with medication regimens could save more than \$50 billion annually in the U.S.⁷

Compliance-assistance technologies can help in many other areas as well. The potential benefits of physical ther-

apy for seniors are often lost, and the costs can even increase, if patients perform rehabilitation exercises incorrectly once they leave the clinical setting. A sensor system that could track body movements and offer specific suggestions via a computerized “coaching agent” could lead to significant improvements in this area.

Determining the most effective means and media for helping people to follow their care plan is a key interdisciplinary research topic. Distributed and mobile interfaces are another topic: how can we help people comply with their care plan no matter where they are?

In health care, personalization technology obviously must maintain rigorous standards. It must also answer the question of how to build adaptive, self-learning systems that automatically tailor individual compliance messages according to past encounters with the device.

4 Support for Informal Caregiving

If the health care system is to scale successfully with the coming wave of seniors, technologies must leverage the current care that friends, neighbors, coworkers, and family members provide. What kinds of interfaces and systems can help adult children care for their aging parents from a distance? What are the privacy, security, legal, and ethical issues involved in remote monitoring of another person’s everyday activities?

Answers to these and other questions can help improve the quality of life of caregivers who provide the backbone of support for functionally disabled seniors around the world.

Home-Based Health Care

Personal wellness systems are not meant to replace the mainframe system of hospitals, clinics, and physicians but rather to put seniors and the activities of daily living more squarely into the health care mix. The home must become as much a locus for health care innovation as the hospital.

Systems that encourage seniors to maintain physical fitness, nutrition, social activity, and cognitive engagement so they can function independently in their own homes for as long as possible can help address the social and financial burdens of an aging population. At the same time, the informal caregiving network of family members, neighbors, and friends—both local and far away—needs new ways to check in on seniors, increase communications, respond to emergency conditions, and avoid caregiver burnout.

Professional caregivers need access to remote, real-time diagnostic data through telemedicine technologies that help them conduct remote checkups on their elderly patients to detect troubling trends such as increased blood pressure or loss of appetite.



Author Eric Dishman shows attendees a device that tests severity of a patient's Parkinson's disease at Intel's Developer Forum

Of course, "home" is not always a house. The hundreds of households participating in Intel studies include very different notions of what "home" means, depending on cultural background, health status, financial means, and proximity to friends and family members.

The ultimate goal of personal wellness systems is to improve the quality of care for seniors no matter where they live, but technology could assist with transitions from one level of care to the next and help prevent premature placement in the more expensive assistance domains.

Testbed for Everyday Complexity

The real challenge for research now is to ... explore the implications and issues associated with having hundreds of networked computers per person. These networked computers will work together to learn our habits and patterns and be proactive in providing us with the information and services we need for a healthier, safer, more productive, and enjoyable life.

—David Tennenhouse, Vice President and Director of Intel Research


It would be foolish for any technology company to ignore either the market that the worldwide "age wave" opens up for home-based health care technologies or the challenge the caregiving burden will present in maintaining a productive workforce. But Intel is also interested in this

domain because it provides a challenging context for developing the next wave of computing and communications technologies.

Personal wellness systems for aging in place offer a unique testbed for engineering systems that support Intel's proactive computing vision (www.intel.com/research/exploratory/). Proactive computing looks beyond the desktop-PC model of human-computer interaction to—as the name suggests—computing systems that anticipate people's needs and take appropriate action on their behalf.

Medication compliance offers a simple example of both the potential and challenge of designing effective personal wellness systems. Many seniors take up to 10 medications per day. Taking the right pills at the right time is often burdensome, and mistakes easily occur. Exact compliance with prescribed courses of treatment could save billions of health care dollars annually.

The state of the art in medication compliance today is an electronic caddy that centralizes pill taking in an automatic dispensing machine that provides audio prompts to take pills at just the right time. However, this model has numerous problems. First, few seniors—at least in Intel's many household studies—put all of their pills in one place. Thus, having a single dispensing site rarely works. Second, people can easily miss the caddy prompts. Moreover, some people deliberately ignore the alerts because they find them to be impersonal, inappropriately timed, or embar-



raising. Further, the system itself has no way of determining whether the right person is actually taking the pills, and it offers little to no assistance if someone gets off the normal medication routine.

Saving lives and significant dollars through improved medication compliance will likely require a complex system of simple technologies integrated with intelligent tracking software. With multiple wireless sensors, a system can be more intelligent about sensing where someone is, whether or not they have opened a pill bottle anywhere in the home, even how interruptible they might be at a given moment.

The reminder can come through any device—perhaps a wristwatch, the television, a phone that is close by, or whatever device has most effectively promoted compliance in the past. The prompt can be suggestive and secretive—a gentle reminder whispered through a wireless hearing aid—or a nagging nuisance such as the television refusing to play again until the right pills are taken. Even the prompt modality—a bland textual reminder on a screen, an audio prompt in a beloved relative’s voice, or an anthropomorphized computer agent that looks and sounds like a pharmacist—can elicit radically different results for different people.

The point is that personalizing even such a simple system poses numerous technical, privacy, and usability problems. The range of sensors, devices, algorithms, applications, and interfaces—all of which must work seamlessly and securely across multiple locations and contexts—shows that, like all proactive computing domains, even beginning to test the efficacy of health technologies for aging in place demands interdisciplinary research and systems-level thinking.

Given that personal wellness technologies and integration must be stable and reliable enough to sometimes help with life-and-death decisions, they will drive a demanding specification for next generation computing that is effective for almost any industry, business, or use.

Case Study: Computing for Cognitive Decline

A good day for Betty is when she is able to make tea for herself. This disease has completely changed our priorities.

**—Jim, caregiver for his spouse,
Betty, who has Alzheimer’s**

A 2002 report showed that the four million Americans with Alzheimer’s disease cost U.S. businesses more than \$61 billion due to lost productivity and health care coverage costs.⁸ Given an estimated increase in Alzheimer’s cases in the U.S. to more than 14 million by the middle of

this century, this disease alone could bankrupt the Medicare system.

Using methods borrowed from anthropological and other social sciences, Intel recently completed observations, interviews, and focus groups of 100 U.S. households that included seniors suffering from conditions ranging from the “normal” memory decline of healthy elders to extreme cases of stroke-based dementia and advanced Alzheimer’s. We sought to understand what needs, problems, and goals personal wellness systems should try to address for everyone involved in caregiving.

The lives of Betty and Jim, participants in our field studies, show the need for a technology that can intelligently adapt to the day-to-day variability of Betty’s declining health as well as to Jim’s increasing needs as her primary caregiver.

Betty was forced to retire early from an engineering career since, like most people with moderate-stage dementia, she now forgets not only names and faces but also the sequences of everyday tasks, such as getting dressed or making a cup of tea. Jim still works full time but does all he can to help Betty remember to eat, drink, and take her medications. He helps Betty practice these activities of daily living, hoping that “practice makes perfect” is still applicable to her mental functioning and will help her maintain her independence as long as possible.

A cup of tea

Inspired by Betty and Jim’s story, we built a prototype system in our lab to prompt and assist someone in fixing a cup of tea and to monitor progress in that activity over time. The prototype system, uses “mote” sensor technology to implement a small plug-and-play processor and wireless transmitter. Motes are tiny, self-contained, battery-powered computers with radio communication links. The technology was originally developed through collaboration between the University of California, Berkeley, and the Intel Research Berkeley laboratory (www.intel-research.net/berkeley).

The prototype system implements five kinds of sensors:

- ★ Off-the-shelf motion sensors for activity detection
- ★ Simple pressure sensors placed in chairs to determine whether or not someone is sitting
- ★ Contact and magnetic switches to sense the movement of drawers, cabinets, or objects in the kitchen
- ★ Radio frequency identification (RFID) antennas situated between the family room and the kitchen to identify foot traffic through small RFID tags placed in people’s shoes
- ★ An infrared-tracking camera that detects whether or not a person wearing RFID badge has fallen down

LEARN MORE

Eric Dishman to Address NHIA in March

Eric Dishman, one of the world's leading experts on digital health care technologies, will give a keynote address at NHIA's 17th Annual Conference in Phoenix (for more information on conference programming, go to www.nhia.org/ac08). Come hear what this pioneering social researcher is learning about the health care—and in-home care—needs of our aging population.

Trained as a communication scholar and social scientist, Eric Dishman, Ph.D., B.A., M.Sc., has used qualitative research methods for more than 13 years to help technology companies understand and invent new market, business, and technology opportunities. As the Founder and General Manager of Intel's Health, Research and Innovation Group, he leads a team that borrows from anthropological and other social scientific methods to interview, observe, and even live with thousands of people around the world at home, work, and play.

Dishman's research has focused primarily on medical anthropology, medical informatics, health care technologies, home health care, chronic disease management, telehealth, and aging-in-place technologies. Most recently, his group has been conducting groundbreaking "behavioral biomarker" research by deploying wireless sensor network, digital home, and machine learning technologies into the homes of seniors for unprecedented early detection, differentiation, and personalized treatment of conditions such as Alzheimer's and Parkinson's.

Dishman has shared his expertise and vision with policymakers and the media in efforts to advocate for the adoption of new technologies and support for further development. He has briefed White House cabinet members and addressed White House conferences, the Senate's Special Committee on Aging, and the National Governors' Association. He is regularly quoted in the mainstream press and was profiled by the *New York Times*.

NHIA 17TH ANNUAL CONFERENCE General Session

Monday, March 10th

9:15 a.m. – 10:30 a.m.

1.25 CEs (nursing and pharmacy)

All of this raw, real-time data travels through the wireless mote network into a host PC for processing, prioritization, and communication.

Because dehydration often afflicts people with Alzheimer's disease, our system can infer that no one has been in the kitchen or opened the cabinets where the mugs are kept. The system waits as long as possible for Betty to remember to get something to drink on her own, but once it reaches a certain threshold of concern, the assistant software locates and prompts her, first with a television commercial for tea, and finally with an explicit textual prompt on the screen.

Even if they can understand and process this kind of reminder, many seniors can forget the prompt as they move toward the kitchen and get distracted by something like seeing mail on the coffee table. We therefore instrumented classic "smart home" technologies like X10 control of the light and sound sources to help keep the person on task.

Once Betty is in the kitchen, the system again waits to see if she needs help making tea. With cognitive conditions, it is critical that the machine not prematurely replace the human's own capacity to act. If Betty is slow to start opening cabinets or moving the teapot, the system finally utilizes the kitchen television to ask if she needs help. If she says "yes," it proceeds to monitor her progress, offering her video instructions of only the steps she misses: finding a mug in the cabinet, finding a tea bag, pouring the hot water, or adding the sugar.

The prototype's inference and assistance capabilities are primitive. Nonetheless, its design goals include not only helping to make tea and perform other kitchen activities but also longitudinally tracking data that shows how much help was needed, how often, and which steps were most difficult. This data can help detect Betty's rate and type of cognitive decline.

Adaptive Functionality

On her more lucid days, Betty can still use the television remote control and utter simple voice commands to interact with a system, but on some days, even simple technologies like a radio prove daunting for her. Unfortunately, Betty's condition is likely to worsen to the point that she could lose both her physical and verbal capacities. At that stage, the system must adapt to provide more support for Jim, the caregiver, than for Betty.

We observed many seniors with advanced Alzheimer's sitting most of their daylight hours in the same chair, but the caregivers' fears about them falling demanded constant vigil and co-presence. Chair sensors and fall detectors can help

monitor the safety of loved ones, thus freeing caregivers to work or rest in other parts of the house. Our current prototype system uses whatever home device is closest to Jim to alert him that “Betty has gotten up,” followed by a more urgent alert of “Betty may have fallen” if the system senses from the infrared cameras that she is at floor level.

Fieldwork First and Last

Again, these systems are only laboratory prototypes. We used them to help instantiate findings from our fieldwork and to begin building out the wireless sensor and electronic device networks for testing personal wellness systems in the homes of real seniors and their caregivers. As we move from the laboratory to real-world trials, we have chosen to tackle something less ambitious than the full activity-detection system described for Betty and Jim. Our current focus is on developing proactive tools to help with what we call “social health monitoring and support.”

In our year of field research, we found that many people with mild cognitive impairment—a condition that progresses into full-blown Alzheimer’s for some people and that stabilizes at milder forms of memory loss for others—went into self-imposed exile and isolation because they could no longer remember the names and faces of even close friends or family members. This social isolation can spiral into depression, and the lack of social stimulus can actually accelerate cognitive decline.

We are building and testing a wireless sensor network that looks for a sudden decline in social contact. The network provides visualizations of social activities and employs a screen phone that uses sensor data to provide rich contextual cues, such as who is calling, when you last spoke, and what you discussed.

We plan to use these kinds of home-based technologies to aid in the early detection of cognitive decline, to embed cognitive assessment metrics into everyday activities such as using the phone, and to help those experiencing decline stay socially active and engaged for as long as possible.

As we move toward developing the infrastructure for inventing wellness systems—in the aging-in-place domain and beyond—the usability issues of proactive health systems could pose the biggest research challenges of all.

Data fusion and visualization applications must turn sensor data into meaningful, actionable information for consumers who have little knowledge of or patience with database queries. Computerized coaches and online assistants must fit appropriately into everyday activities and devices. Data mining applications must compare current health data

both to an individual’s lifelong database and to large volumes of aggregated public health data.

The health care crisis presents both enormous opportunities and obstacles as our planet’s human population ages. If companies, governments, and seniors themselves are to remain healthy in the midst of current demographic changes, we would all do well to answer Sheila’s call for “help helping our aging parents.”

Caregiving needs are inexorably and inevitably becoming part of our everyday lives. Through real-time, real-world data capture about individual biology and behavior, proactive wellness-oriented systems offer fundamental new ways of understanding—and intervening in—aging and disease processes to better manage our health.

Eric Dishman, Ph.D., B.A., M.Sc. is the Founder and General Manager of Intel’s Health, Research and Innovation Group, which is part of Intel’s Digital Health Group. He is responsible for driving global R&D for new health care and wellness-related technologies across the continuum of care from hospital to home. He also directs the Intel Proactive Health Research lab focused on home health technologies for seniors and their families who are struggling with cognitive decline, cancer, and cardiovascular disease.

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