Spring 2009

TECHNOLOGIES FOR AN AGING POPULATION

The BRIDGE

LINKING ENGINEERING AND SOCIETY

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LINKING ENGINEERING AND SOCIETY

Editor's Note

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Editor's Note

George Bugliarello

Engineering for an Aging World Population

The world population is aging. By 2050, the number of people over 65 will increase from 7.8 percent of the global population today (about 500 million) to about 16 percent. By 2016, for the first time in history, people over 65 will outnumber children under five (National Institute of Aging and U.S. Department of State, 2007). The world population is living longer thanks in large measure to better sanitation and improved health conditions.

At the same time, birth rates in many countries of the developed world are declining, thus increasing the percentage of elderly people and altering the age profile of the population. For example, in Russia, Japan, and several European countries, birth rates have fallen below the average replacement level of 2.1 children per woman. By 2030, projections show that Russia's population will decline by 18 million and Japan's by 11 million. Conversely, in many developing countries and in the United States, birth rates are higher than 2.1, and the population continues to increase.

The unprecedented concurrence of plummeting birth rates in some parts of the world, a population explosion in other parts, and a large number of older people everywhere is a complex phenomenon that confronts us with multifaceted challenges: how to enable elderly people to function in a world designed by and large without them in mind; how to reduce the burden on the working population of supporting an increasingly large population of retirees; and how to engage retirees who have the capabilities and desire to continue working. According to a 2003 NRC report on technology for adaptive aging, in the United States participation in the workforce by males over 65 declined from 50 percent in 1950 to about 20 percent today; the participation of women over 65 has remained essentially steady at around 10 percent (Pew and Van Hemel, 2003).

In the United States and several other affluent countries, the problem of supporting senior citizens has been exacerbated by early retirement, by unemployment or underemployment in the working-age population, and by the migration of production and service jobs abroad. This situation can be remedied if the productivity level of the active population that supports non-workers can be increased beyond its already high level, or if the active population is increased by delayed retirements or the re-employment of retirees.

Engineering is critical to meeting these challenges. Engineers can create job opportunities by designing or redesigning workplaces suitable for older employees, by developing devices and techniques to enhance the learning and sensing abilities of older people, and by making the world more manageable, supportive, and friendly for the elderly, enabling them to do the things most of us take for granted. This will mean not only providing easy access to shopping, libraries, and medical offices, but also making it easier for them to open machine-tightened bottle caps, negotiate stairs and other obstacles, read instructions, learn how to use new electronic devices, continue to drive a car, or to take alternative means of transportation safely. Several of these goals are "low hanging fruit," that is, they are relatively easy to achieve if we have the will to do so.

As the United States embarks on a massive, urgent program to revitalize the economy, we should not overlook the opportunity of increasing national productivity and improving the quality of life for a rapidly growing segment of the U.S. population. This will require the development of new technologies and the adaptation of existing technologies, extensive applications of systems analysis to optimize solutions, and the encouragement of new enterprises and new markets focused on leveraging the potential of senior citizens. The ultimate benefits will include a decrease in health care and retirement costs, a more efficient economy, and a better quality of life for all, including the disabled who confront many of the same obstacles as older people.

The framework for meeting these challenges is a broad, interdisciplinary understanding of the cognitive and physical abilities of the elderly and the legal and economic obstacles that must be overcome. By necessity, the five articles in this issue can address only a few of the challenges of our aging world. The papers exemplify the interdisciplinary teamwork that will be required to meet them, and they provide revealing statistics.

Misha Pavel and his coauthors begin with the idea that "it takes a *village*," a team of committed stakeholders, to care for an older person. Pavel and his associates are working on continuous in-home monitoring and assessment for each individual to enable responders to intervene as soon as problems arise. In many cases, caring workers and the creative use of technology can mitigate normal or accelerated declines.

Mobility is the central issue in several papers. Rory Cooper addresses the broad issues of personal wheeled mobility and manipulation technologies that can support people in their daily lives and enable them to engage in community activities and even commute to work. Joachim Meyer focuses on new in-vehicle technologies for older drivers.

Richard Marottoli stresses differences between mobility and ambulation. He notes the necessity of providing transportation for older people living in suburbs and rural areas, as well as in urban settings. He describes potential modifications to vehicles and roadways and the seldom-considered negative consequences of prohibiting older people from driving.

Sara Czaja and Joseph Sharit stress the unrealized potential of technology for improving the quality of life of older people. They underscore the need for changes in governmental and organizational procedures and support for educating more human factors engineers to "improve the fit" between older people and the designed environment.

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Technologies that provide in-time information through unobtrusive, in-home monitoring can improve the daily lives of elders.

Technology in Support of Successful Aging

Misha Pavel, Holly Jimison, Tamara Hayes, and Jeffrey Kaye

Misha Pavel

Holly Jimison

Tamara Hayes

Jeffrey Kaye

Introduction: A Personal Scenario

Earlier today I had a terrifying experience when visiting my 80-something year old parents in their little house in Islip, Long Island. It's not much of a house, but we all love it, and, not surprising, my parents want to live there forever. I was in good spirits as I made the familiar sharp turn into the driveway, reflecting on my last telephone call with my dad just two days ago. He was upbeat—everything was just fine, and both Mom and Dad were looking forward to my visit from Portland, where I am a division head at Oregon Health & Science University (OHSU).

After a seemingly cheerful hug from Dad, I knew instantly something was terribly wrong. Mom did not come to the door, and the house was unusually

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Misha Pavel is professor and division head of biomedical engineering. Holly Jimison is associate professor of medical informatics and clinical epidemiology. Tamara Hayes is an assistant professor in the Department of Biomedical Engineering. Jeffrey Kaye is professor of neurology and biomedical engineering and director of the Layton Aging and Alzheimer's Disease Center. All are at the Oregon Health & Science University in Portland.

dark and messy—even for my parents. A pile of dishes in the sink, the stench of old garbage—this was not Mom's kitchen—a wonderful cook in her day. When I found Mom in her bed, she gave me a big smile, but it was hard for her to move as she attempted to cover up a bruise on her right arm. None of this had come up during my phone call!

Reluctantly, Dad told me that Mom's bruise was caused by a fall in her bedroom several days ago. The scary part was that he hadn't discovered her fall for several hours, even though she was wearing an alert pendant and says she was screaming—at the time, Dad was deeply into his favorite TV show. Mom did not press the pendant because she dreaded the havoc of an ambulance—as had happened with a false alarm a few years ago.

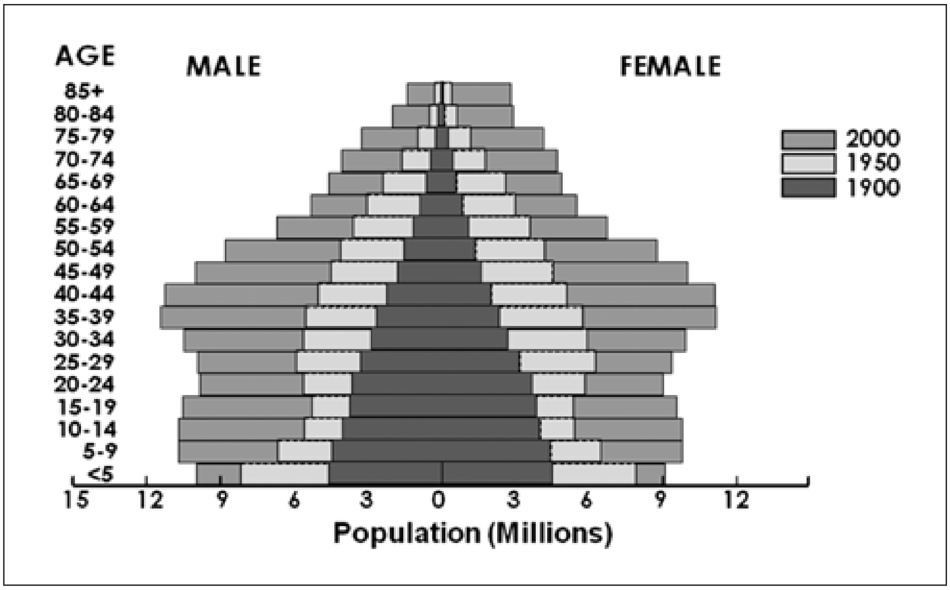

FIGURE 1 This pyramid represents the distribution of ages in the U.S. population at three different points in time (1900, 1950, and 2000). The number of people in each age group is shown on the horizontal axis: males on the left and females on the right. The baby boomers are represented by the bulge in the pyramid for ages 30–54 (in 2000).

Dad also admitted that Mom was sometimes confused, but he did not make much of it because more often than not she was as sharp as ever, and after all, we all have our senior moments. While washing my hands, I discovered a full container of Lasix—medication my Mom swore she was taking religiously once a day. Obviously she was not.

Watching my Dad walk, I could not help noticing a hesitation and shuffle in his gait. It turned out that my parents had stopped taking walks in the nearby park—their main form of exercise—after an unexpected October snowstorm, and they had never resumed them.

I was uneasy. Did Mom have a serious cognitive decline—a mild cognitive impairment? Should I do something? Should I tell their doctor? Should I convince them to move to an elder care facility? I doubt if I could . . . And I live 3,000 miles away . . .

The parents of Misha Pavel described above belong to the fastest growing, economically dangerous, "epidemic" threat to society—the aging population. Figure 1 shows the problem in terms of a pyramid of aging, the number of people in different age groups. Fifty years ago, it was indeed a regular pyramid with straight sides. Today, however, there is a large bulge in the middle—a "tsunami" wave of baby boomers racing toward retirement age.

Economists usually look at this change in terms of the dependency ratio (Figure 2), the ratio of the number of people who need help per working person (i.e., the number of people older than 65 compared to those of working age, 20 to 65). This graph also shows that

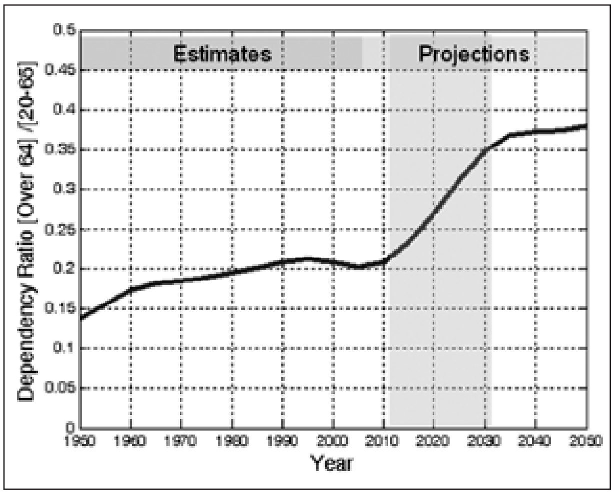

FIGURE 2 The dependency ratio is the number of people older than 64 (presumably retired) compared to the number of individuals in the active workforce (20–64 years of age), plotted as a function of years. The rapid increase due to the baby-boomer population is indicated by the shaded rectangle. Source: *http://www.ssa.gov/OACT/TR/TR06/tr06.pdf*.

when the baby-boomer generation crosses the 65 year boundary (the vertical rectangle in Figure 1), the situation will deteriorate even more rapidly. At that point, instead of seven working people per older adult, there will be only three. Advances in health care and changes in lifestyle have extended the life expectancies of the older generation as well as those in succeeding generations. In addition, these relatively affluent elders expect to continue enjoying a high quality of life and want to remain in their own homes as long as possible.

Unless we find a solution quickly, the economic implications of these demographic changes will be devastating. Fortunately, it appears that technology-based solutions may alleviate many of the challenges in economically feasible ways by enabling proactive health care, efficient care giving by remote caregivers, maintenance of elders' independence, and improvements in their quality of life. In the remainder of this paper, we describe approaches and challenges to technologies for successful aging.

Information Needs and System Requirements

The purpose of the introductory scenario was to illustrate the importance of in-time information in elder care. To understand the need for information, we must first realize that taking care of an elder requires a team. It truly "takes a village"—a team of informal family caregivers, formal caregivers, and health care providers (including geriatricians, neurologists, nurses, and other health professionals), as well as life coaches. Each individual and organization involved in the elder-care team needs different information.

For example, an informal caregiver and a life coach want to know that the elder is engaged and socially and physically active (e.g., how often he or she sees friends). The formal caregiver wants to know whether the elder needs assistance in specific situations and activities, such as hygiene or nutrition. The medical professional wants to be notified when there is a likely reason for medical intervention, such as the onset of a physiological or neurological disorder or an accelerated decline in cognitive or physical abilities. In short, the team needs frequent assessments of activities and health status, including mobility, characteristics of gait and balance, manual dexterity, hygiene, nutrition, weight, blood pressure, medication-taking behavior, and measures of cognitive function, such as attention and memory.

Some of the characteristics of these measurements reflect the medical status of the elderly individual, but others are behavioral markers of physical and cognitive functionality. For example, a decrease in walking speed, in itself, may not necessarily present a problem for the elder. Evidence shows, however, that slower walking or finger tapping may indicate a concomitant or future decline in cognitive function (Camicioli et al., 1998).

A major obstacle in designing reliable monitoring systems is the variability inherent in behavioral assessments. Variability in clinical tests arises from differences among individuals, multiple ailments, unexpected changes and influences, and the inherent variability associated with aging. The traditional approach to assessment based on an in-clinic visit cannot possibly capture the moment-to-moment variability that can be observed informally.

The sensing process must not interfere with normal activity and must require minimal effort.

However, continuous unobtrusive measurements with low-cost sensors have inherent challenges as well as benefits. Sensor data in a natural home environment (as compared to a controlled laboratory setting) are often quite noisy and difficult to interpret on a point-by-point basis. However, by making measurements frequently, it is possible to average out much of the noise. In addition, data from long-term continuous monitoring can be used to assess individual trends and meaningful variability. Thus this approach offers distinct improvements over standard infrequent measurements in a clinic referenced to a population.

Significant individual differences, which occur naturally throughout a lifetime, seem to be exaggerated as people age. Applying population norms—referencing a population distribution—therefore may not be useful for evaluating individuals. Instead, a monitoring system must be adaptable for each individual, and the data must be used as a baseline for the evaluation of further measurements. Finally, because the objective of continuous observation is to assess "normal" behaviors, the sensing process must not interfere with an individual's life and must require minimal additional effort. In other words, measurements must be unobtrusive and require minimal maintenance. Needless to say, these techniques must also be reliable, self-monitoring, affordable, and scalable.

We note in passing that aging is frequently associated with increasing difficulty in adapting to changes, new environments, and new procedures. The implication of this limitation for the assessment process is that an elder's behavior must be observed in the normal living environment (e.g., in the home).

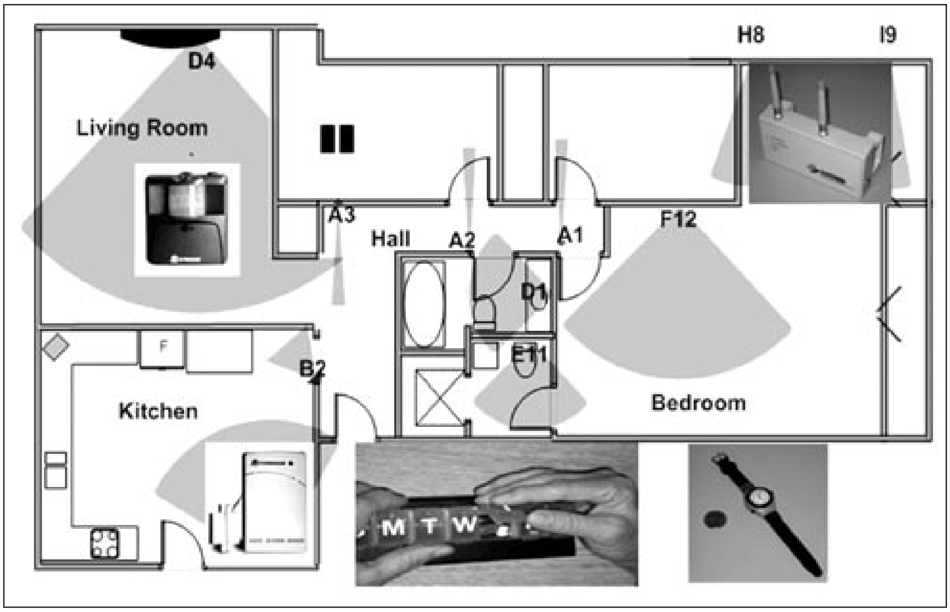

FIGURE 3 Various sensors and devices in a typical home-monitoring installation including IR sensors for tracking motion, contact switches for tracking outings, load cells under the bed, a medication tracker, a phone-monitoring system, a wrist-worn location-monitoring system, and a home computer for tracking computer use.

In recent years, a number of researchers have developed "Smart Homes," test laboratories with sophisticated sensors, devices, and artificial intelligence algorithms that can monitor and make inferences about the details of human behavior. Although these technologically exciting laboratories (Stefanov et al., 2004) may have some benefits, very few of the proposed technologies are ready for widespread in-home use.

One way to mitigate this problem is to move out of the laboratory setting and into the community. For example, one of our studies at the Oregon Center for Aging and Technology (ORCATECH) is based on a so-called "Living Laboratory," about 35 volunteers, living in their own residences, who are outfitted with a variety of sensors and communication systems (described in the next section). Another study, which is primarily focused on gathering clinical data, involves about 250 volunteers who are being monitored in their homes over a three-year period. Simultaneously, they are participating in a traditional clinical longitudinal study. We believe this is the largest trial of its kind.

Unobtrusive Sensing at Home

If we had unlimited resources, it would be possible to outfit dwellings with sensors everywhere, including pressure-sensitive carpets, radio-frequency identification devices (RFIDs), accelerometers and gyroscopes in every item and piece of clothing, a multiplicity of video cameras, and so on. However, the cost of the hardware, installation, software, and service would exceed the cost of one or more human caregivers, thus defeating our purpose. We are looking for monitoring methods that not only meet our requirements for unobtrusive monitoring, but are also affordable and manageable on a large scale.

The actual implementation of the monitoring system in our studies uses inexpensive sensors and systems that are easy to install and require minimal maintenance or intervention (Hayes et al., 2008; Hayes et al., in press; Jimison et al., 2004; Kaye and Hayes, 2006).

A typical sensing system in the "Living Laboratory" is shown in Figure 3. The movement of people in their homes is monitored by passive infrared (IR) motion detectors with pyroelectric sensors (*MS16A, X10.com*). The IR sensors, typically used in home-security systems, sense changes in heat energy from moving thermal sources, in this case, human bodies. The sensitivity of these sensors is sufficient, but their spatial resolution is limited. Thus when an IR motion detector senses a movement that exceeds a fixed threshold, the sensor transmits a message identifying the type of event. Upon receipt, the message is time-stamped and stored on a computer.

To estimate an elder's gait velocity, we installed several motion sensors with restricted field of view to about 8 degrees to ensure precise measurements.

These sensors have been used successfully to measure walking speed in Parkinson's patients (Pavel et al., 2007). In a similar way, various actions, such as opening drawers, doors, and so on, are sensed by magnetic-contact switches (*DS10A, X10.com*). Sleep patterns and weight are observed by load cells under the bed (Adami et al., in press). Medication adherence is tracked by a wireless "MedTracker" (Hayes et al., 2006; Leen et al., 2007; Hayes et al., in press).

In houses with more than one resident, the participants wear active wireless devices (e.g., HomeFree™ *http://www.homefreesys.com/*) to help us identify and localize the individual who triggers a particular sensor (Hayes et al., 2007). These wearable devices include accelerometers, gyroscopes, and sensors to indicate that they are properly worn.

For individuals who use computers, the system records their interactions with their computers during normal usage, as well as while playing specially designed computer games. Developed in collaboration with Spry Learning Company, these games record every move (Jimison et al., 2004). The records are analyzed and interpreted in terms of computational models of the players, in which the parameters of the model represent the key cognitive characteristic. In one game, for example, the system estimates an individual's working memory capacity.

The data from various sensors are collected by a dedicated computer in the home and transmitted securely to OHSU. The raw data are then checked for integrity and stored in a database on secure servers at the university. The data and the functionality of the systems at the client sites are monitored using a comprehensive web-based console tool that provides not only remote monitoring, but also management of the subject cohorts and technologies. Figure 4 shows a view from the console that includes a summary of sensor activities and use of a computer mouse.

In summary, the raw data from remote systems comprise time-stamped events associated with the detection of physical movements, the movement of doors and drawers, and various specialized devices similar to those shown in Figure 3. In the next section we describe how the data are interpreted.

Signal Processing, Pattern Recognition, and Inference

The initial goal of our analysis is to estimate an elder's activity level and the characteristics of certain behaviors, such as gait velocity, medication adherence, and the number and types of outings. This unobtrusive, low-cost measurement system yields data that are only indirectly related to the more variable characteristics we want to measure. For example, instead of a direct measurement of gait velocity, the system records only motion detection.

To compensate for this imprecision, we must develop mathematical models of the relationship between the raw, observed data and the desired characteristics (Pavel et al., 2006a,b). To assess an elder's gait velocity, for instance, we must first select motion-detector data events that are likely to include the desired information and then use them in a statistically efficient way.

The selection of the relevant data from the vast number

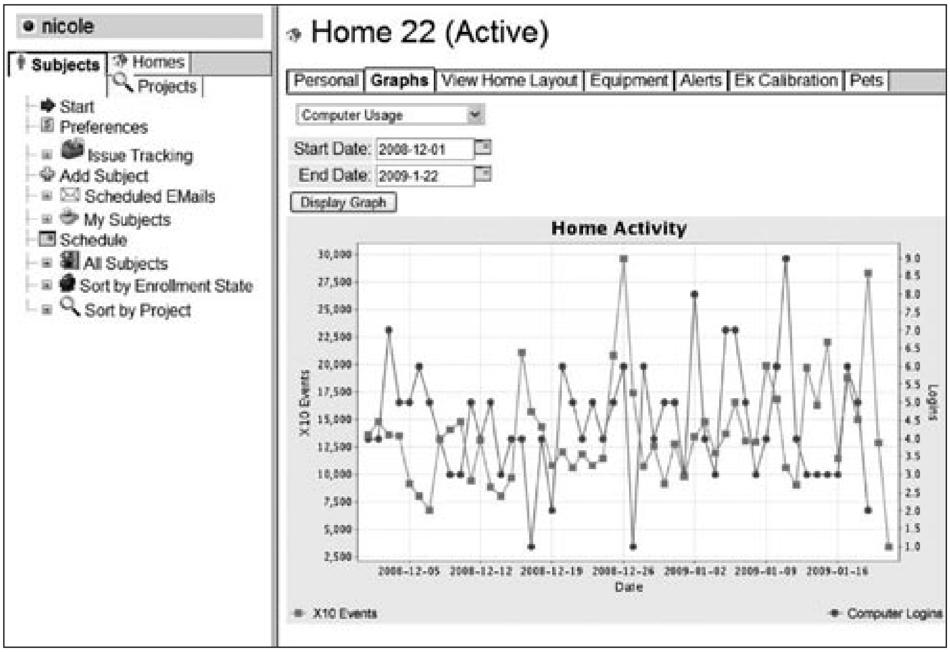

FIGURE 4 This screen shot shows the console used by technicians and clinical research assistants to monitor the subject cohorts, the status of monitoring systems, and the integrity of the collected data. The data shown represent the total activity of the sensors and the number of computer logins.

of observed events requires a computation of the probability that the motion detectors are triggered by the targeted individual, rather than the spouse, visitors, caregivers, or large animals. In a multi-person dwelling, identification of the individual cannot be taken for granted, even if the individual has been asked to wear an identification device. Using such devices for localization is typically based on the strength of the received signal as a function of the distance from a fixed base station. This inference is difficult because the strength of the signal in a real dwelling is highly variable, and contrary to the theory based on open space, the signal strength does not decrease monotonically with distance from the transmitter. This is because of the complex environment of a building with irregular walls, furniture, appliances, and so on.

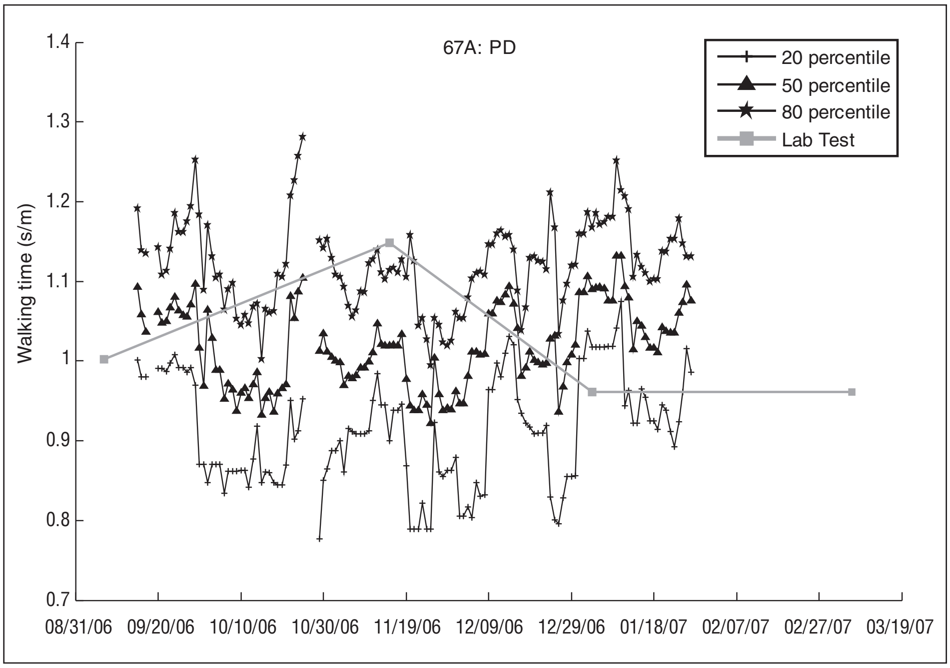

FIGURE 5 Speed of walking in m/sec as measured at home and in the clinic. The three black lines represent the 20, 50, and 80 percentiles, from bottom to top. The values indicated by the square markers are those measured in the clinic.

In one study we used a simple Markov model in conjunction with a triangulation procedure based on the strength of the signal transmitted by devices worn by an elder and spouse and received by several base stations, as shown in Figure 5. The model was used to estimate the location of each individual and then infer the probability that the correct individual had triggered particular motion detectors. In this particular study of elders with Parkinson's disease, we also measured subjects' walking speed in the clinic. The home monitoring estimates and the observed speeds in the clinic were very similar, indicating the reliability of the model (Pavel et al., 2007).

A more sophisticated approach to estimating an elder's location in the home is to use Bayesian recursive estimation, a method that recursively estimates, step by step, the probability distributions of the elder's possible locations (Paul and Wan, 2008). The advantage of this approach is that the estimated location is given in considerably more detail and can be used to assess the elder's activity. We anticipate that this approach would also enable us to detect falls.

With accurate estimates of gait velocity, it should be possible to detect changes that would warrant an intervention. The algorithms developed by our group to detect such changes as early as possible estimate the capabilities of each individual by combining the individual's measurements with those obtained from the larger population. The parameters of these mixed-effect models that characterize the participant's relative performance, such as the slope of the changing speed of walking, are then used to perform the detection (Lu et al., 2009).

Intervention

The ultimate goal of continuous monitoring is to provide information to support decisions to intervene by various caregivers and clinicians. For example, early detection and diagnosis of declines in some functions will enable a health care provider to administer drugs or design an effective mitigation program that may include changes in diet, physical exercise, balance training, or cognitive exercises. In some situations, technology may be used to mitigate problems associated with normal or accelerated decline. For example, the detection of non-adherence to taking medications may trigger the use of a sophisticated, context-aware alerting system (Lundell et al., 2007).

A recent ongoing study involves the development of technology for remote coaching of exercises to maintain cognitive function (Jimison and Pavel, 2008). In this study, volunteers used computer technology to communicate with a health coach, set health goals, and monitor progress toward meeting those goals. We emphasize cognitive-health coaching and include interventions in the form of adaptive cognitive computer games, novelty exercises, physical exercise, and advice on sleep behaviors.

With the approach to health and wellness management described above, we can provide continuity of care with fewer resources. Prompting for coaching messages is automated, and special interfaces with the data are available to family members and clinicians. This type of technology offers a scalable approach to integrating lower cost personnel, as well as motivated patients and family members, into the care team.

Discussion

Technology-based care for elders is a rapidly emerging field at the intersection of engineering, medicine, biology, care-giving, and family life. The management of the multidisciplinary problem of caring for elders requires organizations that bring together experts and practitioners. ORCATECH is one such organization, spearheading one of the largest ongoing longitudinal studies on clinical evidence to investigate unobtrusive monitoring as compared to traditional, clinical assessment techniques.

Although this article is focused on our work at ORCATECH, several other organizations are also addressing these issues. The most comprehensive list of these can be found on the website of the Center for Aging Services and Technologies (*http://www.agingtech.org/index.aspx*). In addition, several well funded projects to address the problems of elder care have been initiated in the European Union. In this short paper, we could not address a multitude of related issues associated with ethics, privacy, and security. However, a good deal of research is under way to address these issues (Alwan et al., 2006; Demiris et al., 2008; Mahoney and Tarlow, 2006; Wild et al., 2008).

In summary, our studies combining unobtrusive monitoring with sophisticated computational algorithms represent the first steps in the development of technology-based care for elders. If these can be successfully integrated into clinical practice and caregivers' workflow, we might avoid the scenario described in the introduction to this article.

Acknowledgments

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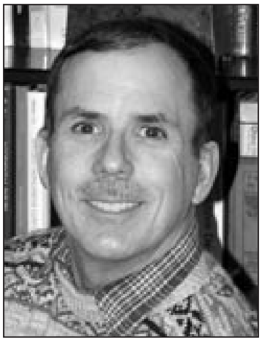
Elders can live more independently and safely in their homes with technologies that provide personal mobility and manipulation capabilities.

Wheeled Mobility and Manipulation Technologies

Rory A. Cooper



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Technology can enhance the quality of life for older people, enable them to live safely in their homes, and enable them to participate in their communities as they age. Technology affects people with different levels of functioning in a variety of settings. In the home, technology may provide personal support and help for daily living. In a neighborhood, technological systems can enable a person to engage in community activities. In the larger community, technology may make it easier for an older person to commute to work and contribute to society through employment.

In each of these settings, technology may improve a person's functionality by enhancing dexterity and mobility, helping with some home chores, reinforcing some kinds of memory, coaching for particular functions, either by providing information or by monitoring and intervening when necessary, and making it easier and safer for older people to drive. In other words, assistive technology may affect almost any aspect of daily life (Cooper et al., 2007).

Although the United States is in many ways an example for other countries in the world to follow, in the areas of assisting people with disabilities, rehabilitating people, and integrating older adults into our communities and culture we are losing ground. Ensuring the availability of assistive technology and accessible environments, providing sufficient support for research and development and adequate health care, and reaching consensus on a definition of disability are all issues we must address. If, as has been said, older people are the "canaries in the coal mine" of American society, the critical precursors of impending disaster, we must find a way to increase support for research, development, and education to create a basis for good decision making, invigorate translational science and engineering capacity for new technologies and services, improve our surveillance to get a better understanding of the problems facing older adults, and reform regulatory policy and legislation to meet their needs (IOM, 2007).

One problem facing every society, whether wealthy or poor, is integrating people with impairments and disabilities into the mainstream of life (Pearlman et al., 2008). The concept of "disability," the interaction between a person's impairment and attitudinal and environmental barriers that keep that person from full and effective participation in society, continues to evolve. Bringing the issues of disability, including the impairments of aging, into mainstream discussions is integral to the development of strategies for sustainable development and civil society. Older adults deserve to maintain their autonomy and independence, including the freedom to make their own choices, and they should have an opportunity to participate in decision making, especially when those decisions directly affect them.

Despite centuries of study, our understanding of older people is rudimentary.

Barriers to the Development and Use of Assistive Technologies

Although a plethora of assistive devices is available in the marketplace and a small research pipeline continues to make progress on assistive technologies, there are also notable individual, technical, policy, and societal challenges to be overcome.

Individual and Technical Barriers

The challenges faced by the individual cut across all other domains. These challenges include, but are not limited to, financial limitations, intellectual capacity, physical ability, sensory impairment, home environment, and the attitude toward technology (Albrecht et al., 2001). Technical barriers are largely defined by the complexity and intimacy of interactions between assistive technologies and older adults.

Human beings are extremely complex. Despite centuries of study, our depth of understanding about older people is still rudimentary. Assistive technology must be used by people with physical, sensory, or cognitive impairment, often a combination of all three. In addition, these technologies must function reliably day in and day out for months, if not years, with little maintenance, often in contact with or in close proximity to the person. An assistive device must function predictably and reliably, do no harm, and degrade or fail gracefully. The more one considers the environment and interactions between a device and its operating environment, the more complicated the design of the device becomes (Cooper et al., 2008a).

Policy Barriers

A few simple examples can illustrate the tremendous impact of public policy, such as Medicare policy, on the development, deployment, and use of assistive technologies by older adults. Most older people rely almost exclusively on Medicare for their primary health insurance.

Other insurance providers, led by Medicare, require that a person's mobility be severely restricted before an electric-powered wheelchair (EPW) can be considered for coverage. Under Medicare, the patient and the rehabilitation team must prove that the person is unable to walk safely in the home. Commonly referred to as the "in-the-home-criterion," older adults must be dependent on wheelchairs to meet their in-home mobility needs before Medicare will consider providing them with an EPW. Taken literally, this means that people must be imprisoned in their homes and no longer able to, for example, pay a social visit, shop, attend church, or go to a doctor's office (Medicare Rights Center, 2005).

This policy led to the ultimate demise of an assistive technology called the iBOT™ transporter (Figure 1), a unique wheelchair manufactured by Johnson & Johnson. The iBOT was an electric-powered chair with a revolutionary design that enabled individuals with impaired mobility to climb curbs, go up and down stairs, balance on two wheels to sit at eye level, and traverse uneven terrain such as sand (Cooper et al., 2004). With the iBOT, users could enter a garden, "stroll" through a park, or converse with a spouse eye-to-eye. These everyday activities, which we often take for granted, are

Figure 1 iBOT transporter in use: (a) balance function for eye-level conversation; (b) standard function for washing hands; (c) remote function for loading in a van.

dearly missed when they are lost. The iBOT provided much more mobility than traditional wheelchairs both inside and outside the home. However, their sophisticated design and concomitant higher cost were deemed a luxury by Medicare and were not fully covered.

Another example is hearing aids, another assistive technology not covered by Medicare, although they are regularly provided by the Department of Veterans Affairs (VA). Hearing loss, one of the most common impairments experienced by older adults, has a profound affect on a person's ability to communicate and on personal safety.

Cultural and Social Barriers

In the simplest case, many cultures place a high value on the ability to walk. This may be entirely natural and intuitive, but it may have the inadvertent and possibly unintended consequence of devaluing people who use wheelchairs. It may also affect the allocation of resources to create an environment that is wheelchair accessible. One need only think of the difficulties and resentment aroused by the passage of the Americans with Disabilities Act (ADA), civil-rights legislation enforced by the U.S. Department of Justice.

Devices that Enhance Mobility and Manipulation

Mobility and manipulation are critical to living independently and are often strongly associated with the ability to continue to live safely in one's home. Simple devices such as crutches, canes, walkers, and rollators (rolling walkers) can assist a person who has the endurance and strength to walk distances, but these devices must also provide some support or feedback to keep the person from losing their balance or enable the person to rest, when necessary. One of the challenges for engineers is matching an individual with the appropriate technology.

Transition to a wheelchair can be a significant personal hurdle for many people, although once the transition is made, it can be a liberating experience (Iezzoni et al., 2001). A common experience of older adults is the gradual contraction of their sphere of mobility; over time, they leave home less and less often. When the appropriate mobility technology, such as a wheelchair, is introduced, their sphere of mobility can once again expand (Hubbard-Winkler et al., 2008). Knowing when to introduce a new device requires assessing a person's capabilities, home environment, and transportation.

Advances in Wheelchair Technology

Critical advances in wheelchairs have been made in the past decade. Manual wheelchairs now make more extensive use of titanium, carbon fiber, and medical-grade viscous fluids, which have resulted in chairs with a mass of less than 9 kilograms (Figure 2). Several studies have shown that reducing the mass of the wheelchair and user system reduces the strain on the arms and increases activity (Collinger et al., 2008).

The greatest engineering challenges in manual wheelchair design are optimizing interaction between the user and the wheelchair, which requires knowledge of materials, biomechanics, ergonomics, anthropometrics,

Figure 2 Ultralight manual wheelchair being driven over a mobility-skills course.

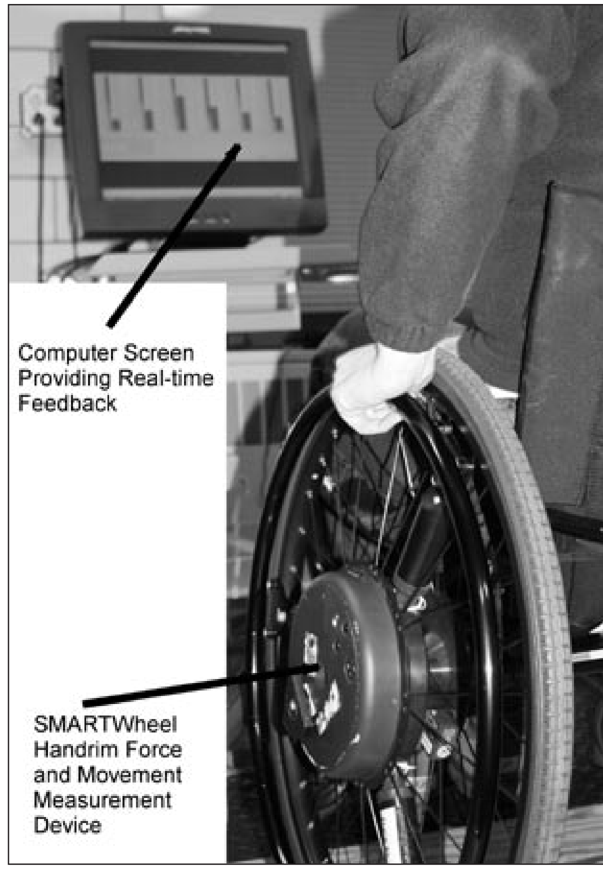

Figure 3 SmartWheel.

and human physiology, as well as motor learning to train the user in the skills necessary to achieve maximum mobility. User-mobility training involves virtual reality, machine learning, remote monitoring, and virtual coaching. In addition, technologies such as the SmartWheel (Figure 3), which was initially developed for research on wheelchair biomechanics, have become increasingly popular as clinical tools for selecting and fitting the manual wheelchair to the user (Asato et al., 1993; Cowan et al., 2008).

Electric-powered mobility is critical to the lives of many older adults. The Segway, although not a medical device, is an attractive alternative to a wheelchair for some older adults who can stand for longer periods of time. It provides outdoor mobility and does not have the negative connotations of using a wheelchair.

EPWs, however, are extremely important sources of mobility for older adults with balance problems, cardiopulmonary restrictions, peripheral vascular disease, and a host of other health problems (Cooper et al., 2006). EPWs can provide comfortable, safe mobility both in the home and in the community.

Control-interface devices (Figure 4) for EPWs enable people to operate their chairs through proportional hand controls (e.g., joysticks, track pads, eraser joysticks), switches that can be operated by various parts of the body (e.g., hand, head, shoulder, foot, knee), and alternative controls that incorporate gyroscopes, accelerometers, and physiological signals (e.g., electromyograms, electroencephalograms). Identifying the optimal interface, positioning it properly, and tuning it for the user provide substantial clinical challenges and opportunities for further research and development. Control algorithms are being investigated to provide traction control, anti-skid braking, anti-rollover capability, and navigational assistance (Simpson et al., 2008).

Wheelchair seating is also extremely important. Researchers must take into account the dangers of pressure ulcers, venous pooling, spasticity, and contractures. EPW seats can be equipped with power functions that provide seat tilt (e.g., the user's limbs maintain the same relative posture, but the seat rotates with respect to the gravity vector), recline, and elevation (Figure 5). These functions enable the user to change seated positions for comfort, to prevent injury, and to perform everyday activities.

Quality-of-Life Technology Systems

An emerging area of technology development is to provide both mobility and manipulation. Some EPW users cannot retrieve a remote control, a book or magazine, or a drink unless it is placed in their immediate proximity. Frequently, older adults must ask family members or assistants to prepare their meals in advance and place them in the refrigerator, so they only require reheating or removing and eating.

Researchers are working on symbiotic systems that are efficient, safe, and reliable for retrieving real-life objects through user, remote, and autonomous devices. An essential feature of these systems is the seamless melding of robotics, with its approach to autonomous systems, with user-operated assistive technology to produce "quality-of-life technology" (QoLT) systems. QoLT systems create a symbiotic interaction of human and technology that maximizes human abilities and the capabilities of the technology in natural environments.

A QoLT that could remove a sealed plastic container from a refrigerator, place it in a microwave oven, heat it, open it, and place it where the user can eat it would be of great value to many older adults. One research project, the personal mobility and manipulation appliance (PerMMA), is being developed to provide these capabilities and more, both inside the home and in the community at large (Figure 6). PerMMA is not merely a wheelchair with "added intelligence" and arms. It is an integrated mobile robotic manipulator with full

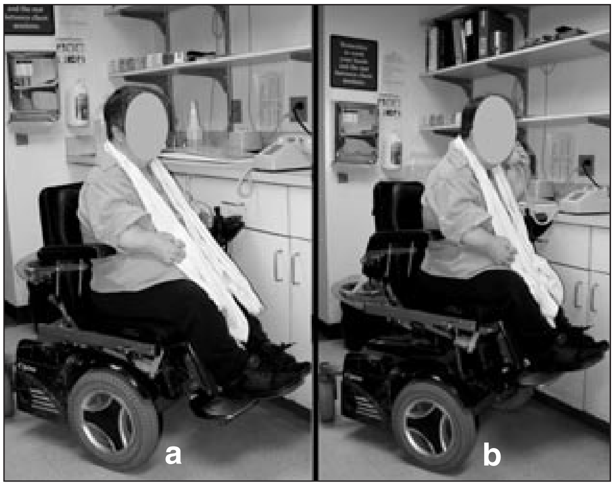

Figure 5 EPW: (a) seat in standard position; (b) seat in elevated position.

seating and EPW functions (Cooper et al., 2008b). A novel approach would be a remote caregiver who could provide assistance with operating a robotic device such as PerMMA to perform novel or difficult tasks. A remote operator could make robotic mobility and manipulation devices available quickly.

Motor Vehicles

Learning to drive is a defining moment in most of our lives. For young people, earning a driver's license is a liberating experience, but for aging adults who lose that privilege, getting around can become a bewildering experience (Odenheimer, 2006). Many mainstream technologies, such as anti-lock braking systems, power steering, traction control, and global positioning systems, have enabled older adults to continue driving as they age. Intelligent-vehicle systems may make it possible for older adults to drive safely even longer as their skills decline.

At some point in the future, a fully autonomous vehicle may actually remove the driver from the control loop; however, many problems must be overcome before such vehicles become marketable. Semi-autonomous vehicles that learn from and provide support to the driver have great potential in the near-term for benefitting older adults.

Figure 4 Control interfaces for EPWs: (a and b) short-throw chin joystick, two views; (c) chin joystick with sip-and-puff switch.

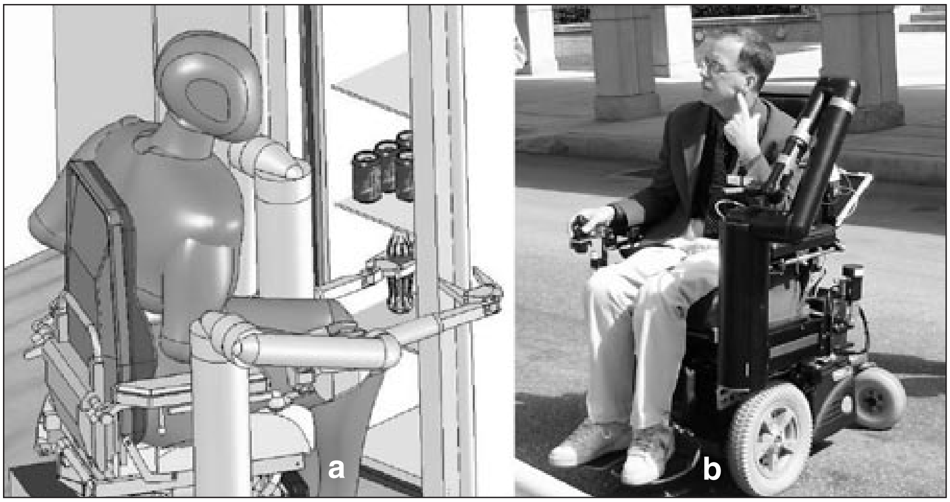

Figure 6 PerMMA, an appliance that provides independent capabilities inside and outside the home: (a) illustration showing use indoors; (b) photo of use outdoors.

Currently, assistance with parallel parking is available from several manufacturers. In addition, systems that recognize driver alertness levels, adjust to lighting conditions, and present drivers with information on their driving performance are being investigated (Ayoob et al., 2003). For people with severe physical impairments, vehicles can be modified to be driven from a wheelchair, fitted with a driver's seat that moves outside the vehicle to simplify ingress/egress, and equipped with alternative primary controls (e.g., hand controls, one-foot driving).

When a motor vehicle is modified, however, the safety of the vehicle may be compromised. For people unable to drive or people who prefer to use public transportation, the ADA requires that buses be accessible along all major routes. Thus buses are equipped with clearance low enough to extend a ramp to the curb so a wheelchair user can roll on and off or an older person can walk on or off without a having to negotiate a step. Because buses are considered low-acceleration environments, compartmentalization (a space or cubicle that confines the motion of a wheelchair) is used to reduce the risk of injury.

Engineers as Clinical Service Providers

The field of clinical-rehabilitation engineering provides not only technical challenges but also opportunities to help others. Engineers may work in medical rehabilitation, vocational, educational, or community-based settings. Clinical-rehabilitation engineers primarily provide assistive technology services to people with disabilities, including older adults. One of the most rewarding aspects for engineers is direct interaction with older adults in determining their needs, identifying or creating technological solutions, implementing and tuning the device or system, and training the older adult to use the device. Helping older adults maintain or regain independence and improve their quality of life can be personally gratifying.

Another feature of clinical-rehabilitation engineering is working as part of a team. Teams often include physicians (often physiatrists), physical therapists, occupational therapists, speech therapists, audiologists, prosthetists and orthotists, and rehabilitation counselors. Each professional has unique knowledge to contribute, but all of them share core values and a strong desire to help older adults.

An unfortunate challenge for clinical-rehabilitation engineers is reimbursement for their services. Most insurance providers do not recognize rehabilitation engineering as a health care profession. Therefore, payment for services must be incorporated into the cost of the technology or built into the overhead of the aggregate of assistive technology services provided by the medical rehabilitation team. Some state agencies (e.g., offices of vocational rehabilitation, agencies on aging) and federal agencies (e.g., VA) have fewer restrictions and may pay for clinical-rehabilitation engineering services. I expect that when clinical-rehabilitation engineering is recognized as a health care profession, the field will experience tremendous growth.

Transforming the Engineering Design Process

Teams of engineers, clinical scientists, social scientists, older adults, and caregivers must work together to relate psychological, physiological, physical, and cognitive function to the design of assistive and rehabilitative technologies. Ultimately, the result must be the creation of systems and devices that have a positive impact on quality of life of older adults. In part, this can be achieved by working closely with them and their caregivers throughout the design, development, test, and deployment phases to ensure that adoption, evaluation, and privacy concerns have been addressed. User involvement should be incorporated into engineering education and encouraged for practicing engineers.

Neither experts (clinicians or engineers) nor older adults and caregivers have complete critical knowledge. Accurate mapping and modeling of the abilities, opinions, experiences, and requirements of users can contribute to the development of successful assistive and rehabilitative technologies. A systematic approach to user involvement is characterized by: (1) the incorporation of universal design principals; (2) active involvement of all relevant parties and a clear understanding of the circumstances of the older adult and task requirements for the device; (3) multidisciplinary research, design, and development involving older adults, engineers, designers, marketers, clinicians, service deliverers, and social and health professionals; and (4) an interactive development process.

A participatory action design (PAD) must include an understanding of the context in which the product will be used and the user's cultural and organizational requirements. Prototypes should be produced and designs evaluated according to the user's criteria. The essence of PAD is a thorough understanding of policy, human assistance, assistive technology, and environmental interaction (the PHAATE model) (Cooper, et al., 2007).

Conclusion

Assistive technology is a cornerstone in the support structure that enables older adults to live independently, to participate in society, and to maintain their quality of life. Engineers continue to make important advances in technologies to assist older adults, and this can be a rewarding career path. Rehabilitation engineers are experts in understanding interactions between technology and people with disabilities in the performance of everyday activities.

Advances in engineering promise a brighter future for older adults. Rapid prototyping and manufacturing have reduced the time from conceptualization to product, and as virtual companies take advantage of flexible manufacturing, small, innovative companies are becoming competitive and earning sufficient revenue producing orphan products. As our understanding of the special needs of people with disabilities or infirmities improves, PAD processes and universal design processes will create crossover products that will help both older and younger people. If policy and societal hurdles can be overcome, robotics, machine learning, contextually aware systems, sensor integration, smart materials, and human-technology-activity modeling can transform assistive technologies.

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New in-vehicle systems must be designed for users who receive no training in how to use them and whose cognitive and sensory abilities vary.

Designing In-Vehicle Technologies for Older Drivers

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Seventy years ago people were already concerned about older drivers having to adjust to changes in cars. In an article on traffic accidents and age, written in 1938, we read ". . . drivers who were trained on 30-mile per hour cars will have to be retrained to drive their improved vehicles safely at the higher rates of speed prevailing on our highways" (De Silva, 1938). The rapid development of technology since then and the aging of the population have greatly increased those concerns.

Today, new in-vehicle systems must be adapted to their prospective users, who receive no specific training on how to use them and whose cognitive and sensory abilities vary. The design of these devices will determine whether or not users accept them and will, therefore, have major business consequences for the companies that market them. In this article I outline some of the challenges facing the designers of in-vehicle devices for an older population and suggest how these devices can be designed and introduced in ways that encourage their success.

The Aging Driver Population

The population in most developed countries, including the United States, is rapidly aging. As longevity increases, the number of people over the age of 65 in the United States is also increasing. In addition, as birth rates decline, older people make up a larger proportion of the general population.

But old age is not what it used to be (and there is little reason to be nostalgic about this). In the past, old age was often associated with disease and disability, but older people today are more active and healthier than ever before. Even though more people are diagnosed as suffering from chronic diseases, such as hypertension and diabetes, the adequate management of these conditions enables them to function without serious disabilities (e.g., Manton et al., 1998). In addition, older people today are better educated than previous generations and more likely to strive to maintain their independence and mobility. These trends are expected to continue in the future.

Older people are also driving more than ever before. This is the first generation in which almost everybody earned a driver's license during adolescence and has been driving ever since. Not surprisingly, therefore, in the U.S. National Household Travel Survey, 89 percent of older Americans (age 65+) reported using personally driven vehicles as their means of transportation (Collia et al., 2003). The percentage of the population over 65 with driver's licenses increased from 62.7 percent in 1982 to almost 80 percent in 2003, and it is likely to increase somewhat more in the future. Therefore, the number of older drivers and their percentage in the total driver population is increasing rapidly (see Figure 1).

Special Needs of Older Drivers

There is no specific age at which a person becomes an older driver. According to De Silva, in 1938, more than a quarter of the U.S. population was over 40 years old, and "persons beyond their forties can not expect to continue to drive at the same rate as they did in their younger days." Indeed, visual abilities do decline from age 40 on (or even earlier), and the decline becomes steeper as we age. Other cognitive and sensory abilities usually change only when a person reaches 60 or 70, and some abilities, such as language skills, may change very little. There are also large individual differences in the onset and extent of these changes (see Meyer, 2004, for an analysis of aging and driving). Most statistics on older drivers set the cutoff age around the age of retirement (60 or 65), but empirical data show gradual changes with age and no clear transition from a middle-aged to an older driver.

A number of these changes are particularly important for driving and the use of in-vehicle devices. Among them are age-related changes in night vision, contrast sensitivity, recovery from glare, and a decrease in the useful field of view (UFOV) (i.e., the width of the visual field over which information can be acquired in a quick glance). Aging is also accompanied by general slowing in processing speed. The initiation of responses and their execution become slower, especially for unexpected events (Olson and Sivak, 1986).

It seems logical that age-related changes in drivers' abilities would make them more accident-prone, but older drivers are by and large safe drivers. After age 60, the number of traffic fatalities per billion kilometers driven increases steadily (Evans, 2004), but this increase is mainly due to older people's fragility rather than their greater involvement in accidents (Li et al., 2003). Older drivers are likely to be fatally injured in an accident from which a younger person may walk away almost unharmed. Only after age 80 does the involvement of older drivers in accidents exceed the involvement of 20 to 29 year olds. Thus older drivers seem to be able to compensate effectively for age-related changes, for instance, by limiting themselves to daytime driving,

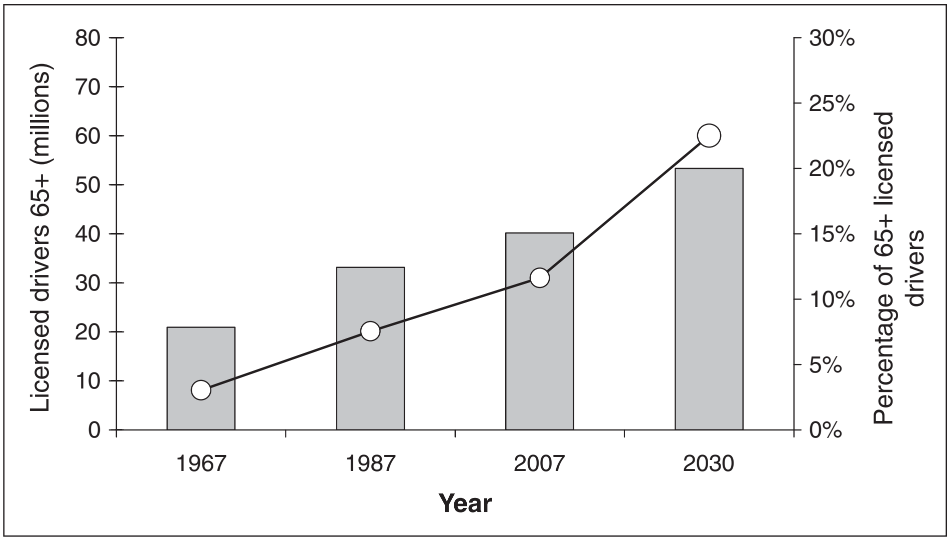

Figure 1 Number and percentage of drivers 65 years of age or older in the U.S. driver population. Source: Federal Highway Administration statistics and predictions (*www.fhwa.dot.gov*).

using familiar routes, and avoiding difficult traffic situations (see Chapter 7 in Shinar, 2007, for a description of the driving characteristics of older drivers). Of course, Alzheimer's disease and other cognitive and sensory disorders may impair a person's ability to drive safely (e.g., Dubinsky et al., 2000), and people suffering from such diseases should cease driving.

New Technologies in Cars

Although cars and driving are changing faster today than at almost any other time in the last century, driving a car manufactured in the 1950s is very similar to driving a one produced in 2000—the speed is regulated by pressing the accelerator and the brake pedal, and direction is controlled by turning the steering wheel. The information for driving is mainly collected by looking through the windows, both in normal driving and when backing up and maneuvering.

Today, however, new technologies are being introduced into the car that alter the way the driver controls the vehicle (for a description of many of these systems, see Ashley, 2008). Typical examples are adaptive cruise control (ACC), which allows a driver to maintain a constant speed, but also a constant distance from vehicles traveling in the same lane. Thus speed is no longer solely controlled by changing the pressure on the accelerator or brake pedal. The car automatically accelerates and decelerates within preset limits.

The information available for driving is also changing. Various types of warnings are now installed in cars, including forward-collision warnings, backup warnings, and lane-departure warnings. Night-vision systems and various cameras provide drivers with visual information. These and other enhanced vision systems are becoming additional sources of information for controlling the vehicle. They give drivers a better understanding of the driving situation and make it more likely that they will detect obstacles and hazards.

Cars are also increasingly equipped with devices that support tactical aspects of driving. These include navigation systems that help a driver find a route toward a destination by providing turn-by-turn directions or by showing the route on a map display. They may also provide traffic advice, informing a driver about congestion, accidents, or road work, and can help a driver choose a route with minimal delays.

Finally, systems to entertain the driver and passengers are also rapidly changing. Such systems have been in cars, in the form of car radios, since the early 1930s, but they have greatly evolved. Today systems with combined advanced communication and computing capabilities provide not only entertainment, but also access to information. In addition, they can communicate with people outside the car. The use of these devices is usually unrelated to the driving task itself. Examples of such systems are car entertainment systems, cellular phones, text message systems, and in-vehicle e-mail and web access.

Many cars today use the same computer system to interact with all three types of devices. For instance, a computer display may show the view from a rear-facing camera when the car moves backward. The same computer may also show route information for navigation and provide access to the entertainment system or a screen for reading text messages. Although these devices can have great benefits for a driver, they can also interfere with safe driving.

Well designed technologies can limit the effects of age-related changes.

Older Drivers and New In-Vehicle Systems

New in-vehicle systems create particular challenges for older drivers. Paradoxically, even though older drivers may find it more difficult to use these devices, they are likely to be the first to encounter them, because innovations are often initially introduced into high-end cars, which are usually bought by more affluent (and usually older) costumers. Thus the more mature driver population is often the first to encounter still immature systems.

Older drivers can, of course, benefit from new systems. When well designed, technology can limit the effects of age-related changes. For instance, a major problem for many older people is decreased flexibility. In a survey of older drivers in the United Kingdom, more than half of the respondents mentioned difficulties with turning their heads and looking out the rear windows (Herriotts, 2005). The reduced motility of the neck and head, combined with a narrower useful field of view, may increase the likelihood that an older driver will collide with an object behind the car when backing up. When changing lanes, older drivers may also be less likely to see a vehicle coming from behind in a parallel lane.

Alerts and visual aids, such as rear-view camera systems, can help alleviate these problems. But for older drivers to benefit from them, their designers must consider the users' abilities and characteristics. For example, interfaces should be as simple and intelligible as possible. Almost everyone over the age of 60 has trouble focusing sharply on nearby objects, a condition called presbyopia, and most people require corrective lenses to view close objects (Weale, 2003). While driving, drivers will not put on reading glasses to use a system, and they may find driving with bi- or multifocal glasses unpleasant. Therefore, in-vehicle displays and devices should be designed so that drivers with presbyopia can still use them. Some evidence has shown that older drivers particularly benefit from multi-modality displays that combine visual and auditory information (Liu, 2000). However, hearing loss is also fairly common among older adults. Thus designers must also take this into account in designing auditory displays.

Learning new skillls and changing routines become more difficult with age.

The design of intelligent interfaces that predict and support drivers' actions can also help alleviate age-related problems. For instance, in a recent study in our laboratory, we examined the performance of older and younger drivers while using an in-vehicle telematic system (Lavie and Meyer, 2008). We compared performance with various levels of adaptivity in the telematic system. A system with the highest level of adaptivity could predict a driver's actions and perform them automatically. At lower levels of adaptivity, the driver chose from a suggested list of possible actions. In the fully adaptive mode, the performance of older and younger drivers and their use of the system were almost the same, as long as the system correctly predicted the driver's intentions. Thus intelligent, adaptive software may make these devices safe and acceptable for older drivers. However, the systems must be very reliable. In our study, an incorrect prediction of a driver's intention had a much more adverse effect on older drivers than on younger ones.

A number of factors may make the introduction of new in-vehicle devices problematic for older drivers. The main advantage of older drivers is probably their long experience with driving, which makes them, overall, very safe drivers. However, the need to learn new skills, related to new devices, may render their previous experience obsolete. Although people are often able to perform familiar tasks and skills up to a very advanced age, learning new skills and changing familiar routines becomes more difficult with age (Craik and Jacoby, 1996).

Even apparently simple systems, such as rear-view cameras, require learning new skills. Common driving situations, like backing out of a garage, involve a coordinated set of complex actions related to the collection of information (by turning the head, etc.), decelerating and accelerating, and turning the steering wheel. When using a rear-view camera, the driver must look at the screen in front of her, and not turn the head, and use the information from the screen to control the steering of the car. Thus the driver must change well established routines, which may be more difficult for older drivers.

Distraction is another issue that may affect the adoption and safe use of new technologies by older drivers. With age, the ability to focus and divide attention tends to decrease (e.g., Greenwood and Parasuraman, 1997). In-vehicle devices often require that a driver divide attention between driving and using the device. Some evidence of these difficulties was apparent in the survey of older drivers in the United Kingdom (Herriotts, 2005). Many of them said they had problems with their car radios; others said they did not have problems because they simply never used their radios when driving. If an older driver is distracted when using in-vehicle systems, he or she may compensate by driving slower and leaving more space between the vehicle and the car ahead (Merat et al., 2005).

If an older driver learns to use a new system, there is a real danger of what has been called "automation bias," or "complacency" (Parasuraman and Riley, 1997). If a driver comes to rely entirely on the new system, for example, a backup warning system, a lane-departure warning, or an intelligent cruise control system that maintains spacing between cars, he or she may eventually begin to initiate a lane-change maneuver without bothering to look, assuming that the warning system will issue a cue if the lane is occupied. However, these systems are considered convenience systems and are not designed to be safety systems. They are, therefore, not sufficiently reliable to be the main source of information for initiating a maneuver.

Also, drivers may not understand the limitations of new technologies. In a survey of the use of in-vehicle technology by young and older drivers, many respondents indicated that they expected these systems to be useful even in situations for which they were not designed (Jenness et al., 2008). For example, more than half of the respondents said they expected a backing aid system (which sounds an alarm when the car approaches an obstacle while backing up) to issue a warning when backing out of a driveway into the street and into the path of an oncoming car. The rate of misperception of the conditions in which the system might be useful was the same for older and younger drivers. However, if older drivers eventually learn to rely on the system to compensate for age-related changes, their misperceptions could have more severe consequences.

Conclusions

Technology should be designed for people, which includes considering aging drivers. We must design cars (and technology in general) so that older people can use them, and, more important, so that new devices make life more comfortable, safer, healthier, and better overall for older people. This is not purely altruistic—designing for older people is likely to benefit everyone. Older people do not need different systems, but they are less able to compensate for a bad design.

A technically well designed system may provide major benefits for older drivers, but it may also turn out to be useless or even to cause harm. To make the success of a system as likely as possible, its design must be based on an understanding of older drivers' characteristics and needs. Thus this is an instance in which "user-centered design" is particularly important (e.g., Owens et al., 1993). The designer should take into consideration theories, research, and recommendations from human-computer interaction (HCI or CHI), cognitive engineering, ergonomics, and human-factors engineering (e.g., Helander et al., 1997; Shneiderman and Plaisant, 2004; Wickens and Hollands, 1999).

At the same time, although extensive research has been done in all of these fields, there are still large gaps in our knowledge of how to design in-vehicle devices, especially if they will be used by older drivers. A major research effort will be necessary to fill these gaps. We should strive for the development of advanced engineering models of users in general, and older users in particular, specifying their characteristics and predicting their responses to different system designs. We are still very far from having such models. Most of the time we are grappling with different design suggestions and comparing them without the aid of such a model.

Conducting the research and developing models of technology use, particularly by older people, is one of the major intellectual, scientific, and engineering challenges of the 21st century. Meeting that challenge will require the collaboration of engineers, psychologists, physicians, researchers, and practitioners in many other disciplines.

The insights gained from such efforts will have implications for almost all domains of life, not just vehicle design. Technologies designed with an eye to older users will not only provide an important service for older drivers and society as a whole by increasing mobility and making driving safer, but are also likely to be a major business opportunity in the 21st century.

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The cessation of driving can have positive consequences for society but serious negative consequences for older people.

Safe Mobility for Older Persons

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In recent years, the discussion of safe transportation for older people has expanded beyond driving to include a range of options for providing out-of-home mobility. In this context, the term "mobility" is not a synonym for ambulation but is used in a broader sense to mean how a person gets from one place to another outside the home. Many factors have influenced this paradigm shift. One of the most important was that limiting the discussion to who could still drive safely and how those who were no longer safe drivers should be evaluated and de-licensed addressed only part of the issue and left the larger, looming question of "what now" unanswered.

For people who have to limit or stop driving, there is a large void to be filled to mitigate the negative practical and psychological effects of no longer being able to drive. A detailed discussion of this issue, including research developments, practical applications, and future directions, can be found in *Transportation in an Aging Society: A Decade of Experience* (TRB, 2004) and a companion document, *Safe Mobility for Older Americans: Report of the Committee for the Conference on Transportation in an Aging Society* (TRB, 2005).

Still, the traditional emphasis on risk was understandable. Motor vehicle crashes are a leading cause of "accidental" injury and death in people 65 years of age and older, a group that is growing rapidly as the general population ages. Coupled with the increased susceptibility of older persons to injury because of their decreased reserve capacity, safety concerns are understandable.

However, the importance of driving to a person's sense of independence and well-being must also be taken into account, particularly for people in North America. Older persons depend on cars far more than other modalities for transportation, either as drivers or passengers. Moreover, in our society out-of-home mobility provided by driving is a key factor in being able to participate in social and productive activities, which in turn have been associated with lower risk of mortality and better functional status (Glass et al., 1999). Indeed, the cessation of driving has been linked to a number of negative outcomes, including a decrease in participation in out-of-home activities, an increase in depressive symptoms, and possibly an increase in the likelihood of nursing home placement (Freeman et al., 2006; Marottoli et al., 1997, 2000).

Older people sustain about 37,000 injuries a year getting into or out of cars.

A sense of these negative consequences, which has long been evident in clinical practice, has led to reluctance on the part of both patients and clinicians to discuss the topic or to assess the underlying risk factors of driving difficulties. In an early survey, many physicians reported that they were reluctant to address the issue because of the potential negative consequences for their patients and the lack of options in many locations to fill the mobility gap if people had to stop driving (Drickamer and Marottoli, 1993). Increasing awareness of the need to provide transportation options and make people aware of those options have been major contributors to the paradigm shift in thinking described above.

Although much of the early research in this area was on medical conditions and functional impairments that might contribute to safety risks, recent efforts have focused more on determining whether interventions to improve drivers' functions or adapt to impairments might improve driving performance and safety. It is hoped that a combination of the availability of interventions, and evidence of their effectiveness, coupled with the availability and awareness of transportation options, will encourage drivers, families, and clinicians to engage in discussions of this sensitive topic and ultimately lead to a better balance between safety, autonomy, mobility, and participation in out-of-home activities.

Demographics and Travel Patterns

The number of older drivers is increasing, both because of the aging of the population as a whole and the relative increase in the population of older people, largely women, who continue to drive, as compared to women their age in the past. In the United States, the vast majority of trips by older persons, even of very advanced age, still depend on their driving, or being driven in, private automobiles (Rosenbloom, 2004).

Although the absolute number of crashes involving older drivers is low, crash rates increase when they are adjusted for mileage. Older individuals are two- to four-fold more likely to be injured, hospitalized, or killed (probably because of their decreased reserve capacity) than younger individuals in crashes of similar magnitude (Barancik, 1986; Fife, 1984). Motor vehicle crashes are the leading cause of "accidental" death for individuals 65 to 74 years old and the second leading cause for individuals 75 to 84 years old (Dellinger and Stevens, 2006). Not all injuries occur in crashes, however; older individuals sustain approximately 37,000 injuries a year getting into or out of vehicles, more than 40 percent of these due to falls (Dellinger et al., 2008).

Although advancing age per se does not increase the risk of crashes, certain older drivers are at risk because of functional limitations, medical conditions, or the effects of medication. Limitations in vision (distance acuity, peripheral fields, contrast sensitivity), cognition (visual attention, processing speed, visual-spatial ability, and executive function), and physical ability (flexibility and speed of movement) have been associated with poor driving performance or crashes, as have medical conditions such as cardiac arrhythmias, dementia, Parkinson's disease, sleep apnea, and stroke (Decina and Staplin, 1993; Drachman and Swearer, 1993; Findley et al., 1998; Freund et al., 2005; Larsen et al., 1994; Legh-Smith et al., 1986; Marottoli et al., 1994, 1998; McLay, 1989; Owsley, 2004; Owsley et al., 1991; Whelihan, 2005).

Crashes involving older drivers are most likely to occur at intersections, particularly when making left turns across traffic (Griffin, 2004; Mayhew et al., 2006). Individuals who drive fewer than 1,800 miles per year also appear to be at increased risk, probably because of the circumstances in which they drive (urban areas with more traffic and intersections) and possibly because of functional limitations (Keall and Frith, 2006; Langford et al., 2006; Lyman et al., 2001). However, older people who drive more than 1,800 miles are often able to drive safely on highways and tend to have lower crash rates (Keall and Frith, 2004; Langford et al., 2006).

Effects of Driving Cessation

Several community-based studies (Campbell et al., 1993; Jette and Branch, 1992; Kington et al., 1994; Marottoli, 1993) have found similar risk factors for driving cessation: advancing age, female gender, poor health (either self-perceived or neurological or visual disorders), and functional limitations (in basic or instrumental activities of daily living or higher level physical activities). However, driving cessation in itself can also have negative consequences, including decreased participation in out-of-home activities, increased depressive symptoms, and increased risk of nursing home placement. The potential consequences of cessation, coupled with the association of participation in social and productive activities with lower mortality risk and better functional status, suggest that a potential downward spiral may be triggered in part, or compounded by, driving cessation.

Interventions

Improving Medical Conditions and Functional Abilities

Growing evidence about risk factors and the negative effects of driving cessation have led to the development of a number of interventions to determine if driving safety can be enhanced and prolonged. Interventions focused on improving medical conditions or functional abilities have, in fact, demonstrated that driving safety can be improved. Successful interventions in this category include removal of cataracts, which can restore and improve vision and, hence, driving capability (Owsley et al., 2002); training to increase the speed of information processing, which can enhance activities of daily living, as well as driving performance (Ball et al., 2007; Roenker et al., 2003); and range-of-motion and speed-of-movement conditioning, which can enhance driving performance and control (Marottoli et al., 2007).

Educational Interventions

One approach to intervention focused on education is combined classroom and on-road driver training (Figure 1), which has been found to improve on-road driving performance and road awareness (Bedard et al., 2008; Marottoli et al., 2007b). Another approach has been to make people more aware of their functional impairments, which often results in their voluntarily driving less often and in less risky situations (Owsley et al., 2003).

Modifications to vehicles and roadways can improve driving safety.

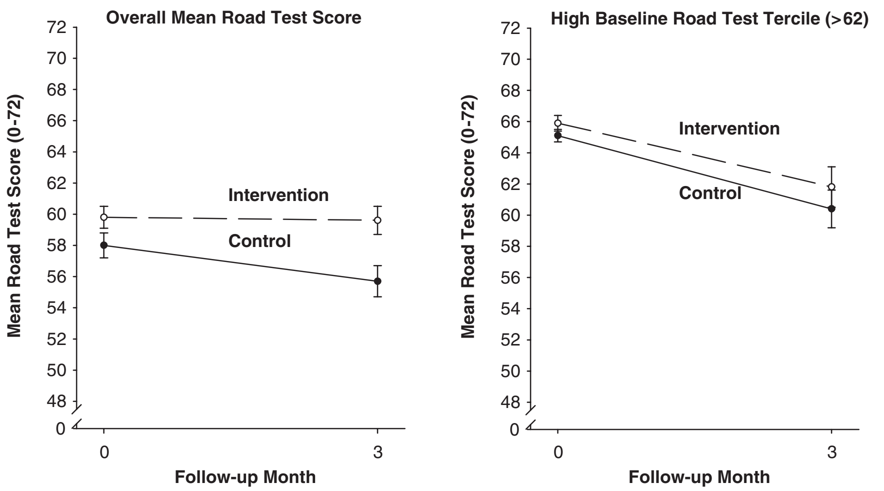
Modifications to Vehicles

The interventions described above were focused on driver capabilities. However, other avenues for intervention include changes in the driver-vehicle and driver-roadway interfaces. In this regard, it is helpful to consider the Haddon injury matrix of factors that occur before, during, and after a collision involving the driver, vehicle, and roadway (Marottoli, 1993; Pike, 2004). Modifications that can help avoid collisions and injuries include making it easier for people to enter and exit the vehicle, designing seats for driver comfort and movement, making vehicle controls more visible to make interaction with them easier, improving outward visibility and the use of mirrors, ensuring the use of safety belts, and the presence of technologies such as antilock brakes and traction control.

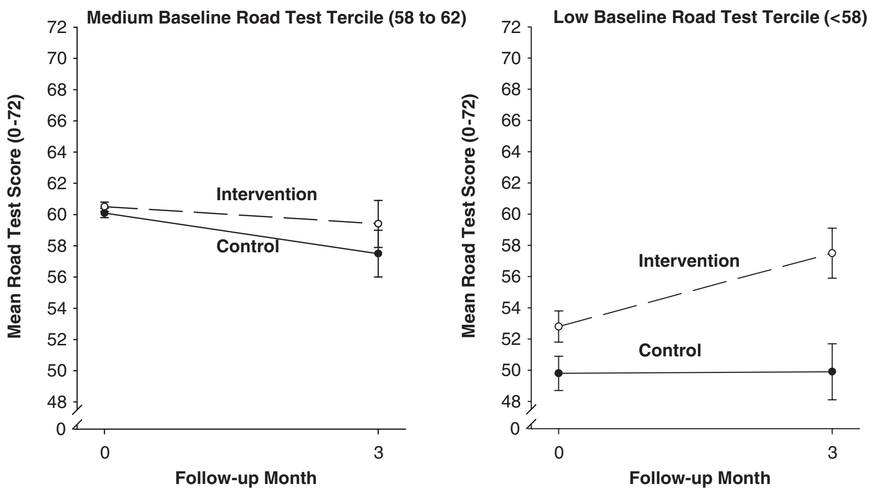
In the event of a crash, the most important factors are safety belts and air bags, the structural integrity of the vehicle, and mechanisms that limit contact with hard vehicle surfaces. After a crash, important factors include automated signaling systems that alert emergency responders and technology that informs emergency crews of the severity of damage and the likely severity of occupant injury.

Modifications to Roadways

Because left turns across traffic are a particularly dangerous maneuver, many recommendations have been made for changes to intersection design to make these turns safer. Given the functional impairments commonly encountered among older drivers, particular attention has been paid to designing intersections so that drivers making turns can see oncoming traffic clearly, that left-turn lanes are protected, that signs are easily visible, and that signals provide enough warning time for older drivers to respond (Schieber, 2004; Staplin, 2004).



	I	C	DIFF	I	C	DIFF
N*	84	90		28	31	
LSMEAN†	-0.40	-2.83	2.43	-4.02	-4.70	0.68
SE	1.03	1.12	1.12	1.46	1.52	1.91
p-value	0.702	0.012	0.032	0.007	0.002	0.722



	I	C	DIFF	I	C	DIFF
N*	31	26		25	33	
LSMEAN†	-1.29	-3.12	1.83	4.49	-0.32	4.81
SE	1.47	1.61	1.93	1.66	1.55	1.93
p-value	0.381	0.055	0.345	0.008	0.835	0.014

*Four participants in the intervention group (3 in low baseline tercile and 1 high baseline tercile) did not complete the follow-up road test exam.

†LSMEAN is the least squares mean change in road test score at 3 months relative to baseline from the multiple regression model adjusted for recruitment site, driving evaluator and baseline driving tercile.

FIGURE 1 Comparison of road test scores at baseline and three months for intervention and control groups.

Design strategies include having protected left turn lanes with a green-arrow signal and providing a "positive offset" at intersections that do not have green-arrow signals so that the turning vehicle is in a position to see oncoming traffic clearly before turning. Considerable efforts have also been made to modify signs and signals to reduce the risk of crashes and to protect pedestrians who must have adequate signals and traffic/speed control to allow sufficient crossing time (Langlois et al., 1997; Oxley et al., 2004).

Other roadway design changes that can reduce the risk of crashes, or minimize the risk of injury if crashes do occur, include removing fixed roadside obstacles, enforcing speed limits, lengthening merging lanes on highways, and using low-glare lighting, high-traction surfaces, and high-visibility lane markings and signs. Considerable efforts have also been made to use sign materials and letter fonts and symbols that maximize their visibility for all drivers under all conditions.

Other Transportation Options

As people limit their driving or stop driving altogether, they must rely on other transportation options to enable them to maintain out-of-home mobility and activity levels. A broad range of options may be available, depending on the person's capabilities and limitations, geographic location (urban, suburban, or rural), and financial resources (Suen and Sen, 2004). Key features to be considered have been called the "five A's of transportation": availability, accessibility, acceptability, affordability, and adaptability (Kerschner and Aizenberg, 2004). Part of the challenge is identifying existing options in a given area and determining how many of the key features they have.

After private cars, the most common option in many areas is walking, highlighting the importance of pedestrian safety (Suen and Sen, 2004). Urban areas typically have affordable public transportation options, because shorter distances are involved and infrastructure is more extensive. In less densely populated areas, informal transportation must be relied upon.

Public transportation options (such as buses, subways, and rail) typically operate on fixed routes with set schedules and pre-determined stops; they sometimes also have a flexible route that can be modified for picking up and dropping off passengers. In addition, paratransit services, private taxis, and livery services may provide a range of options.

Land-Use Planning and Retirement

Another approach is to define how retirement and land-use planning interact (Giuliano, 2004). One area of focus in studies of decisions about where people decide to live and retire is how transportation-related factors enter into their decisions. Another factor is how communities adjust to the aging of their populations in terms of ensuring pedestrian safety and providing transportation options. In some cases, communities are designed from the outset to meet the needs of older persons.

Future Directions and the Role of Technology

At each juncture outlined above, there are many areas that need further investigation or that can be improved. Even though we already have substantial evidence of effective interventions, our knowledge in many areas is limited, and we surely must improve the efficiency and dissemination of information about successful interventions.

In addition, many uncertainties and variables are likely to change over time, such as the characteristics of vehicles and roads, as well as the capabilities and limitations of drivers and transportation users. We must keep an open mind and apply our existing knowledge with the overriding goal of keeping older persons as safe and mobile as possible.

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Human factors engineers can greatly increase the independence and improve the quality of life for older people.

The Aging of the Population:
Opportunities and Challenges for Human Factors Engineering

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Dramatic changes are taking place in the demographic structure of the United States and other countries (Figure 1). An estimated 22 percent of the population will be over the age of 65 by 2030, and the fastest growing cohort within this subgroup will be people over 75. Currently about 44.5 million people are over the age of 75; by 2050 they will number almost 50 million (Figure 1) (NCHS, 2005). Similar changes are occurring worldwide. By 2030 the percentage of people aged 65+ will be about 24 percent in Europe and about 12 percent in Asia and Latin America.

The aging of the population presents vast societal challenges to ensuring that our infrastructures can support the needs of older people enabling them to live healthy, independent, and productive lives. To meet these challenges, we must rethink our conceptualizations of aging and redefine what it means to be "older." The cohort of older adults today is very different from previous cohorts of older people, and the next cohort of the elderly, who will be mostly "baby boomers," is also likely to be different from today's elderly.

In general, older people today are healthier, more diverse, and better educated than previous generations, and many are pursuing active lives. For

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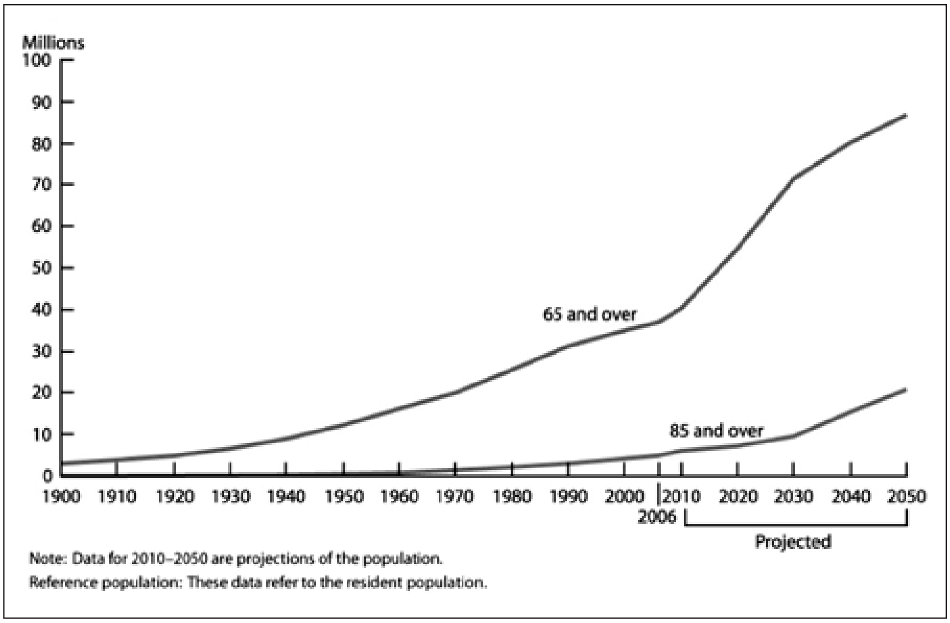

FIGURE 1 Changes in the age distribution of people 65 and older in the U.S. population over the last century and projected through 2050. Source: U.S. Census Bureau, Decennial Census, Population Estimates and Projections.

example, many older adults, either out of need or by choice, remain employed in a full- or part-time capacity; some are even pursuing new careers, and many are engaged in volunteer work. The increase in the number of older workers requires changes in government and organizational policies, work procedures, and educational and training systems. Many older people are also engaging in continuing education, recreational activities (e.g., competitive sports), and travel.

Overall, older people are living longer than ever before, and the number of older people reporting very good health and improvements in physical functioning (e.g., the ability to walk a mile or climb stairs) has increased in recent years. Nevertheless, the likelihood of a person developing a disability or chronic illness increases with age. Many older adults are disabled in one or more aspects of self-care and, in general, the elderly require more health care services and incur higher health care costs than younger people. As the elderly population increases and people live longer, more people will require help with aspects of daily living and disease management.

Normative changes in function also occur with aging. For example, aging is accompanied by declines in visual and auditory acuity, a slowing of reaction and response times, declines in motor skills and agility, and changes in cognitive processes such as lapses in memory and attention. Thus there is a clear need for strategies to help healthy older people remain productive and independent and to ensure that those who are frail or disabled receive care and support so that they can live in their communities for as long as possible. Age-related changes in function have vast implications for the design of products, environments, and activities.

Diffusion of Technology

Simultaneously with the aging of the population, we are witnessing unprecedented development and the diffusion of technology into all aspects of everyday life. Currently, all forms of technology, including computers, communications, safety, and health monitoring devices, are being used to perform routine tasks and activities. The use of technology has become an integral component of work, education, communication, and entertainment.

Technology is also being increasingly used in the health care arena for the delivery of services, in-home monitoring, interactive communication (e.g., between patient and physician), the transfer of health information, and peer support. As communication protocols evolve, we can anticipate more sophisticated network applications that can provide faster and more powerful interactive services in the future. Intelligent technologies will also increasingly become embedded in our interactions with the environment, and robots performing daily tasks will be commonplace. People of all ages will interact with some form of technology to function independently and engage effectively in their surroundings.

Technology has great potential for improving the quality of life for older people. For example, telemedicine/e-health will improve the physical and emotional well-being of older people. Technology can also enable older people to remain connected to family and friends, especially with those who are distant. Technology can also help older people remain employed and maintain or upgrade their skills, or it can ease the transition to retirement.

To date, however, evidence shows that the potential benefits of technology for older adults have not been realized. In 2007, about 32 percent of people age 65+ were Internet users, as compared to 65 percent of people age 50 to 64 and 83 percent of people age 30 to 49. Older adults who use computers and the Internet tend to be well educated and white and have more social resources and fewer functional impairments than non-technology users. The number of older people who have adopted home broadband is also lower than in the general population. In 2007, only 15 percent of people aged 65+ had broadband access at home, which limits the scope and potential of their online experience (Pew Internet & American Life Project, 2006, 2007). The widespread use of technology in the larger society suggests that the lack of technology use among older adults will have increasingly negative implications. For example, older people, who are most likely to need medical care, may not have access to health care technologies.

To date, older adults have largely been ignored as a viable user group by designers of technology systems. Although older people will have more technology experience in the future, they may still have problems adopting or negotiating technologies with new features unless system designers perceive older adults as an important user group and take their needs into account. The age-related digital divide could be closed if efforts are focused on that goal.

Many system designers do not take the needs of older adults into account.

Human Factors Engineering

Human factors engineering, the study of human beings and their interactions with products, equipment, and environments in the performance of tasks and activities, could have great benefits for improving the independence and quality of life of older people. The overall objective of human factors engineers is to improve the "fit" between people and the designed environment to maximize performance, safety, comfort, and user satisfaction and minimize the likelihood of errors, inefficiencies, injuries, fatigue, and user dissatisfaction. To achieve this objective, human factors engineers espouse a user-centered, systems approach to design in which age-related changes in capabilities, tendencies, and preferences are incorporated into guidelines for design of products, tasks, and environments (Rogers and Fisk, 2000).

User-centered design can address the problems of older adults and help them retain and enjoy independence in their later years. In the following sections, some examples are presented of how older people could benefit tremendously, especially in the areas of information technologies, health care, and employment, from the application of human factors principles and concepts. These examples illustrate opportunities for human factors engineers.

Health Care

The likelihood of developing a disability or chronic illness increases with age, and many older adults are unable to perform one or more self-care tasks. In general, the elderly require more health care services and incur higher health care costs than younger people. The application of human factors and ergonomics principles and methods to the design of assistive and information technologies can improve the lives of elders in the areas of e-health, medication adherence, health care delivery, warnings and instructions, home safety, and the design of assistive devices.

Improving Medication Adherence

Failure to take medications as prescribed is a common problem among older adults and a significant predictor of hospital admissions. Generally, the person fails to take a prescribed medication, takes the incorrect dosage, takes medications at improper times or in the wrong combinations, or fails to comply with special instructions such as dietary restrictions. Noncompliance is particularly problematic for older people who take multiple drugs and are susceptible to side effects and drug interactions.

The problem of medication non-adherence is complex and may be attributed to numerous factors, such as an individual's perceptions or beliefs (e.g., the person does not believe that he or she is ill or that the medication is effective), cognitive problems (difficulty comprehending or remembering medication instructions), or ineffective strategies to encourage compliance. Many of these factors can be addressed by engineering solutions to help offset memory problems associated with comprehending and integrating medication schedules.

Products and devices could be designed to improve the organization of medications, such as calendars, electronic pill dispensers, and compartmentalized containers that are congruent with a medication schedule. Voice mail or beepers might be used to remind individuals to take medications. Automated telephone messaging is effective not only for medication adherence, but also for reminding people of appointment times and for monitoring chronically ill patients and older adults who live in the community and are not being monitored in health care, assistive, or other facilities. Other engineering solutions include improvements in the packaging and labeling of medications and educating individuals about the nature of their illnesses and the importance of medication in illness management. The appropriate intervention depends on an understanding of the reason for non-adherence (Park and Jones, 1997).

Improving Health Care Delivery

Engineering and technology applications can improve health care delivery for people who are frail or have limited mobility, facilitate access to health care information and services, and make it easier for health care professionals to deliver care. For example, computers and information technologies, such as e-mail and the Internet, can give older people access to information about a particular illness, medication, diet, or exercise program. Technology can be used by health care providers to communicate with older patients; remind them of appointments and home health care regimens, such as dietary schedules; and check on a patient's general health status.

Interactive health communication, or "e-health," generally refers to the interaction between an individual and an electronic device or communication technology (such as the Internet) that provides access to information, transmits health information, or provides health-related guidance and support (Robinson et al., 1998). The scope of e-health applications is fairly broad, but most applications involve searching for health information, participating in support groups, and consulting with health care professionals. Millions of websites currently provide health information, and in 2006 about 113 million Americans searched for health information online on a typical day (Pew Internet and American Life Report, 2006).

The fact that consumers have access to e-health applications has significant implications for both patients and providers. On the positive side, access to health information can empower patients to take an active role in their health care. Patient empowerment can result in more informed decision making, better and more individualized treatment decisions, stronger patient-provider relationships, increased patient compliance, and better medical outcomes. On the negative side, access to such a wide array of health information can overload both patient and physician, disrupt existing relationships, and lead to poor decision making on the part of consumers.

Access to health information can empower patients, but too much information can be overwhelming.

The Internet can help older people communicate with health care providers or other people with similar problems. Several studies have shown that online support groups are beneficial for this population (Fogel et al., 2002). The Internet may be particularly beneficial for hearing impaired or aphasic individuals. However, for these technology-based applications to be successful, the technology must be relatively simple to use, readily available, and affordable, and adequate training must be provided. In addition, designers should take into account the credibility of information, privacy issues, and trust.

The term "telemedicine" refers to a wide range of technologies, from simple telephone connections to live two-way video and audio transmissions (interactive television). With telemedicine, physicians can directly assess patients and measure blood pressure, gait, and cognitive status. Physicians can also measure vital signs and ask hypertensive patients about disease manifestations and drug side effects. The cost of the technology varies with the sophistication of the system.

Finally, personal health records, especially patient-oriented electronic medical records (EMRs), can bring together fragmented information from multiple sources. A study committee of the Institute of Medicine concluded that EMRs are necessary to improve the quality and decrease the costs of medical care and recommended that patients have unfettered access to their own medical information (IOM, 2001).

Patient-oriented EMRs are being designed to provide tailored information that can be accessed through online patient portals. Patient portals to EMRs also have the potential to personalize health education according to an individual's demographic characteristics and medical conditions. In addition, they can supply decision-support tools that can synthesize a great deal of medical information into linguistically appropriate messages for that individual.

Despite the growing popularity of EMRs, little research has been done on the usability of these tools for patient self-management, especially for at-risk populations such as older adults who are already experiencing a much larger variety of health problems than other segments of the population. Although the number of patient-accessible EMRs is increasing, many of them have not been evaluated to establish their usefulness and usability. Widespread public acceptance of EMRs and other e-health tools will require that designers pay more attention to the needs and circumstances of intended users, including their experience with health information and digital technologies and their capacities for health self-management (DHHS, 2006).

By 2010, there will be 26 million workers age 55 or older.

Employment and Work Settings

Current demographic projections indicate that by 2010 there will be about 26 million workers in the United States age 55+, a 46 percent increase since 2000. By 2025, the number will increase to approximately 33 million (GAO, 2003). The number of workers age 65+ will also increase substantially. Parallel trends have been identified in other developed countries throughout the world.

In addition to changes in demographics, we are also witnessing changes in the structure of work organizations. For example, vertically integrated business organizations are becoming less-vertically integrated, specialized firms. Decentralized management, collaborative work arrangements, and team work, and a new paradigm of knowledge-based organizations in which intellectual capital is an important organizational asset are also becoming commonplace. These changes in work structures and processes will have a pronounced effect on the nature of work and on the required capabilities of workers.

Ongoing developments in technology are also reshaping work processes, jobs, workplaces, and the delivery of job education and training. The introduction of automation and computer technologies into the workplace has dramatically changed the nature of many jobs and work situations.

To ensure that older adults can adapt to new workplace technologies, employers must provide them with access to retraining programs and incentives to invest in learning new skills and abilities. In addition, training and instructional materials should be designed for older learners, and technologies themselves should be designed (or modified) to be usable and useful for older adults, especially people with some type of impairment.

The benefits of new work arrangements (e.g., teleworking) should also be explored for older workers. Telework may be particularly appealing to older adults, who are more likely than younger people to be "mobility impaired" or engaged in some form of care giving (Schulz and Martire, in press). Telework also allows for flexible work schedules and autonomy and is amenable to part-time work.

There are also challenges, however, associated with telework for both workers and managers. The challenges for workers include isolation, managing home and work responsibilities, and the lack of technical support and feedback from managers and co-workers. For managers, the challenges relate to supervision and management of workers and decisions about which workers are best suited to telework. A more fundamental concern is that most teleworkers must interact with computers and the Internet or some other form of technology to perform their jobs. Although some data suggest that older workers are receptive to telework opportunities (Sharit et al., 2004), in general limited systematic evaluations of telework, especially with older workers, have been done.

Areas for Future Research

Human factors engineering focuses on improving interactions among people, tasks, environments, and products. The application of human-factors and ergonomics principles can improve the health, safety, and quality of life of older people. The basic premise of human factors and ergonomics is that user-centered design, based on a fundamental understanding of user capabilities, needs, and preferences, will lead to improvements in performance. Thus, according to this principle, improving the health and quality of life of older people requires that the knowledge of aging be applied to the design of products and environments.

For example, in today's health care and work environments the ability to use technology is a critical skill. Technology can greatly improve the well-being and quality of life of older adults, and studies indicate that older people are receptive to using new technologies. However, they often encounter difficulties because they receive inappropriate training or because designers of the technology have not taken into consideration the needs of older people. User testing and user-centered design are critical to the success of technical systems. Guidelines for human-computer interaction suggest how computers and other forms of technology can be useful to, and usable by older adults (Czaja and Lee, 2002, 2006; Fisk et al., 2004).

We currently know very little about the efficacy of design aids and support tools for older adults. We also need more information on the best way to train older adults to use new technologies, and there are many unanswered questions about the best designs of online training programs and multimedia formats.

Issues of privacy and trust in technology are critical areas for research. There are also many questions about the Internet, such as how access to Internet information impacts health care behavior and how we can teach seniors to identify and integrate relevant information from the enormous amount of information available on the Internet.

In the workplace, research on how technology impacts employment opportunities and the work performance of older people would be extremely helpful. Not much research has been done on telework as it relates to older people or the factors that influence technology adoption, especially for minority elderly people and people who are not highly educated or well off economically.

Finally, many questions related to quality of life and socialization have not been fully explored. Many of the needs of older people could be addressed, or partly addressed through technological solutions. However, we will first need a systematic effort to understand their needs and incorporate them into the design of products for the marketplace.

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NAE News and Notes

Class of 2009 Elected

In February, NAE elected 65 new members and 9 new foreign associates, bringing the number of members to 2,246 and the number of foreign associates to 197. Election to NAE, one of the highest professional distinctions accorded to an engineer, honors those who have made outstanding contributions to "engineering research, practice, or education, including . . . significant contributions to the engineering literature" and to "new and developing fields of technology, . . . major advancements in traditional fields of engineering, or . . . innovative approaches to engineering education." A list of the newly elected members and foreign associates follows, with primary affiliations at the time of election and brief descriptions of principal accomplishments.

New Members

Paul M. Anderson, consultant, Power Math Associates, San Diego, California. For contributions that have advanced the analysis and control of electric power systems worldwide.

Kristi S. Anseth, distinguished professor and Howard Hughes Medical Institute Investigator, Department of Chemical and Biological Engineering, University of Colorado, Boulder. For pioneering the rational design of biomaterials for tissue engineering, drug delivery, and biosensing applications.

Diran Apelian, Howmet Professor of Mechanical Engineering and director, Metal Processing Institute, Worcester Polytechnic Institute, Worcester, Massachusetts. For contributions to solidification processing and for outstanding leadership in engineering education and university-industry collaboration.

David C. Auth, consultant, Kirkland, Washington. For the invention and application of minimally invasive devices for the treatment of gastrointestinal bleeding and coronary artery obstructions.

Amos A. Avidan, senior vice president, Bechtel Corporation, Houston, Texas. For contributions to the understanding, scale-up, and commercialization of fluid-bed reactors, liquefied natural gas facilities, and gasification plants.

Jay P. Boris, chief scientist and director, Laboratory for Computational Physics and Fluid Dynamics, U.S. Naval Research Laboratory, Washington, D.C. For fundamental contributions in core computational fluid dynamics algorithms and their application to national problems.

Frank (Skip) L. Bowman, former chief of naval personnel and former director, Nuclear Propulsion Program, U.S. Department of the Navy, North Potomac, Maryland. For leadership in the design of nuclear-reactor propulsion plants to support the power requirements of evolving combat systems.

Sergey Brin, co-founder and president of technology, Google Inc., Mountain View, California. For leadership in the development of the rapid indexing and retrieval of information from the World Wide Web.

Selim A. Chacour, president, American Hydro Corporation, York, Pennsylvania. For pioneering three-dimensional finite element computations in mechanical and hydraulic design, leadership in hydroturbine research and development, and business stewardship.

Moustafa T. Chahine, senior research associate, Jet Propulsion Laboratory, Pasadena, California. For leadership in determining the structure and composition of the Earth's atmosphere from space observations.

Jean-Lou Aristide Chameau, president, California Institute of Technology, Pasadena. For national and international leadership and contributions in engineering education, geotechnical engineering, and public policy.

Yet-Ming Chiang, Kyocera Professor, Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge. For contributions to understanding of new energy storage materials and their commercialization.

Robert Leon Cook, vice president of advanced technology, Pixar Animation Studios, Emeryville, California. For building the motion picture industry's standard rendering tool.

Arthur J. Coury, Coury Consulting, Boston, Massachusetts. For contributions to design and commercialization of pacemakers, biodegradable biomaterials, and implantable devices.

William J. Dally, chief scientist and senior vice president of research, NVIDIA Corporation and Willard R. and Inez Kerr Bell Professor of Engineering, Stanford University. For contributions to the design of high-performance interconnect networks and parallel computer architectures.

Jeffrey Dean, Google Fellow, Google Inc., Mountain View, California. For contributions to the science and engineering of large-scale distributed computer systems.

Jack B. Dennis, Professor Emeritus, Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology, Cambridge. For contributions to sharing and protection in computer systems and parallel architectures based on data flow principles.

Mark Drela, Terry J. Kohler Professor of Fluid Dynamics, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge. For creation of breakthrough aircraft designs and design software that enabled operation in new flight regimes.

Deborah L. Estrin, director, Center for Embedded Networked Sensing, University of California, Los Angeles. For the pioneering design and application of heterogeneous wireless sensing systems for environmental monitoring.

S.M. Farouq Ali, president, Petroleum Engineering Research Laboratories Canada Ltd., Edmonton, Alberta, Canada. For pioneering techniques for enhanced oil and gas recovery.

Stephen N. Finger, retired president, Pratt & Whitney, East Hartford, Connecticut. For leadership in the design, development, and manufacture of advanced military and commercial gas turbines and advanced rotorcraft.

Stephen P.A. Fodor, founder and executive chairman, Affymetrix Inc., Santa Clara, California. For pioneering and commercialization of very-high-density DNA arrays, enabling massively parallel genomics.

Gerard J. Foschini, distinguished inventor, Alcatel-Lucent, Bell Labs, Holmdel, New Jersey. For contributions to the science and technology of wireless communications with multiple antennas for transmission and receiving.

Donald P. Gaver Jr., distinguished professor of operations research, Naval Postgraduate School, Monterey, California. For contributions to reliability, maintainability, and queuing concepts, with applications to telecommunications and military systems.

Sanjay Ghemawat, Google Fellow, Google Inc., Mountain View, California. For contributions to the science and engineering of large-scale distributed computer systems.

Jean-Pierre Giroud, independent consultant, JP GIROUD INC., Ocean Ridge, Florida. For pioneering research in geosynthetics engineering and its practical application in civil/geotechnical engineering.

Andrew Jackson, senior scientific adviser and program lead, ExxonMobil Research and Engineering Corporation, Annandale, New Jersey. For contributions to tribology and research in elastohydrodynamic lubrication, fatigue, machine efficiency, automotive emissions, and synthetic lubricants.

Kanti Jain, professor, Department of Electrical and Computer Engineering, University of Illinois, Urbana. For contributions to the development of high-resolution, deep-ultraviolet excimer lithography for microelectronic fabrication.

Ahsan Kareem, Robert M. Moran Professor, Department of Civil Engineering and Geological Sciences, University of Notre Dame, South Bend, Indiana. For contributions to analyses and designs to account for wind effects on tall buildings, long-span bridges, and other structures.

Chaitan Khosla, chair and professor, Department of Chemical Engineering, Stanford University, Stanford, California. For engineering molecular assembly lines, developing metabolic engineering technologies, and advancing biopharmaceutical discovery.

John Kim, Rockwell International Professor, Department of Mechanical and Aerospace Engineering, University of California, Los Angeles. For development of direct numerical simulation and seminal contributions to the understanding of the physics and control of turbulent flows.

Paul C. Kocher, founder, president, and chief scientist, Cryptography Research Inc., San Francisco, California. For contributions to cryptography and Internet security.

Christopher B. Lofgren, president and chief executive officer, Schneider National Inc., Green Bay, Wisconsin. For development and implementation of supply-chain engineering concepts, software and technology for truck transportation, and third-party logistics.

Mark S. Lundstrom, Don and Carol Scifres Distinguished Professor of Electrical and Computer Engineering, Purdue University, West Lafayette, Indiana. For leadership in microelectronics and nanoelectronics through research, innovative education, and unique applications of cyberinfrastructure.

William S. Marras, Honda Endowed Chair, Department of Industrial and Systems Engineering, Ohio State University, Columbus. For developing methods and models used to control costs and injuries associated with manual work in industry.

Michael J. McGuire, Michael J. McGuire Inc., Los Angeles, California. For scientific contributions that have improved the safety and aesthetics of drinking water.

Robert D. Miller, manager, advanced organic materials, IBM Almaden Research Center, San Jose, California. For invention of polymeric materials for lithography, porous dielectrics, and processes in microelectronics.

Chad Alexander Mirkin, director, International Institute for Nanotechnology, and George B. Rathmann Professor of Chemistry, Northwestern University, Evanston, Illinois. For development of DNA programmable inorganic materials and dip pen nanolithography.

Umesh K. Mishra, professor, Department of Electrical and Computer Engineering, University of California, Santa Barbara. For contributions to development of gallium-nitride electronics and other high-speed, high-power semiconductor electronic devices.

C. Mohan, IBM Fellow, IBM Almaden Research Center, San Jose, California. For contributions to locking and recovery algorithms for database systems.

Edward I. Moses, principal associate director, National Ignition Facility and Photon Science Directorate, Lawrence Livermore National Laboratory, Livermore, California. For outstanding scientific and engineering leadership of the National Ignition Facility.

Charles Noelke, DuPont Fellow, DuPont, Fayetteville, North Carolina. For development and commercialization of green chemistry and processes, especially for CFC alternatives and fluoropolymers.

Matthew O'Donnell, Frank & Julie Jungers Dean of Engineering and professor of bioengineering, University of Washington, Seattle. For contributions to biomedical ultrasonics and real-time ultrasound imaging technologies.

George A. Olah, Donald P. and Katherine B. Loker Chair in Organic Chemistry and director, Loker Hydrocarbon Research Institute, University of Southern California, Los Angeles. For contributions to the development of chemical technologies for environmentally favored and carbon-neutral energy conversion.

James F. Pankow, professor, Department of Chemistry and Department of Civil and Environmental Engineering, Portland State University, Portland, Oregon. For contributions to understanding the chemical thermodynamics of organic particulate matter in urban air and the global atmosphere.

Stavros S. Papadopulos, founder and senior principal, S.S. Papadopulos & Associates Inc., Bethesda, Maryland. For pioneering contributions to statistical methods for estimating groundwater flow and contaminant transport.

Stuart S.P. Parkin, IBM Fellow and manager, magnetoelectronics, IBM Almaden Research Center, San Jose, California. For contributions to development of spin-engineered magnetic heterostructures for magnetic sensors and memory devices.

Claire L. Parkinson, senior scientist and Aqua Project Scientist, NASA Goddard Space Flight Center, Greenbelt, Maryland. For leadership in understanding sea-ice changes through remote measurements and for leading NASA's Earth Observing System Aqua mission.

Percy A. Pierre, vice president and Professor Emeritus, Department of Electrical and Computer Engineering, Michigan State University, East Lansing. For service as assistant secretary of the Army, contributions to engineering education, and leadership in creating the national minority engineering effort.

Chris D. Poland, chairman and chief executive officer, Degenkolb Engineers, San Francisco, California. For leadership in the development of performance-based design procedures and standards for evaluating seismic events and rehabilitating buildings.

Doraiswami Ramkrishna, Harry Creighton Peffer Distinguished Professor of Chemical Engineering, Purdue University, West Lafayette, Indiana. For creation of new model concepts and solutions that improved the engineering of biological and particulate processes.

Mendel Rosenblum, associate professor of computer science and of electrical engineering, Stanford University, Stanford, California. For fundamental contributions to computer operating systems and virtual machines.

Robert A. Scholtz, Fred H. Cole Professor of Engineering, Department of Electrical Engineering, University of Southern California, Los Angeles. For contributions to the fields of ultra-wideband and spread-spectrum communications.

Gurindar S. Sohi, John P. Morgridge Professor and E. David Cronon Professor of Computer Sciences, Departments of Computer Sciences and Electrical and Computer Engineering, University of Wisconsin, Madison. For contributions to the design of high-performance, superscalar computer architectures.

Howard A. Stone, Vicky Joseph Professor of Engineering and Applied Mathematics, Harvard University, Cambridge, Massachusetts. For the development of fundamental concepts and novel applications in microfluidics and for improving the understanding of small-scale, viscous-flow phenomena.

John A. Swanson, president, Swanson Analysis Services Inc., The Villages, Florida. For development of general-purpose finite-element software used in engineering design worldwide.

Richard Marker Swanson, president and chief technical officer, SunPower Corporation, San Jose, California. For invention of the point-contact solar cell for increased efficiency of commercial solar energy.

Edwin L. Thomas, department head and Morris Cohen Professor of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge. For development of novel photonic materials and determination of the morphology of block copolymers.

Robert W. Tkach, director, Transmission Systems Research, Alcatel-Lucent, Bell Labs, Holmdel, New Jersey. For contributions to research and development of terabit/second optical-fiber communication systems and networks.

Stephen David Umans, consultant, Belmont, Massachusetts. For outstanding teaching and contributions to the development and understanding of electric machinery.

Mark W. Verbrugge, director, Materials and Processes Laboratory, General Motors Research & Development and Strategic Planning, Warren, Michigan. For the development and application of electroanalytical methods for advanced batteries, supercapacitors, and fuel cells for hybrid and electric vehicles.

Alan R. Washburn, Distinguished Professor Emeritus of Operations Research, Naval Postgraduate School, Monterey, California. For analytical contributions to search theory and military operations research and their application to antisubmarine, mine, and information warfare.

Lawrence M. Wein, Paul E. Holden Professor of Management Science, Graduate School of Business, Stanford University, Stanford, California. For model-based research to characterize and improve homeland security operations.

William L. (Red) Whittaker, Fredkin Professor of Robotics, The Robotics Institute, Carnegie Mellon University, Pittsburgh, Pennsylvania. For pioneering contributions to fielded, mobile, autonomous robots.

Paul G. Yock, Martha Meier Weiland Professor, School of Medicine, and professor of bioengineering, Stanford University, Stanford, California. For invention of rapid-exchange catheters, intravascular ultrasound imaging, and the smart needle, and for innovations in bioengineering education.

New Foreign Associates

Monika Auweter-Kurtz, president, University of Hamburg, Hamburg, Germany. For development of electric propulsion and re-entry technologies that advanced space missions and for commitment to aerospace education.

Jurjen Anno Battjes, Professor Emeritus, Delft University of Technology, Delft, Netherlands. For international leadership, research, and teaching in coastal engineering and storm protection.

Sébastien Candel, professor and head, Ecole Centrale Paris and Institut Universitaire de France, Chatenay-Malabry. For significant contributions to solving multidisciplinary problems in the fields of combustion, fluid mechanics, aeroacoustics, and propulsion.

Xianghong Cao, chief technology officer, China Petroleum and Chemical Corporation (SINOPEC), Beijing. For innovations and leadership in petroleum refining and petrochemical production technologies and for leadership in international collaboration.

Brian L. Eyre, senior visiting fellow, Department of Materials, University of Oxford, United Kingdom. For understanding of neutron irradiation-induced damage in materials and for developing technologies and policies for the U.K. nuclear industry.

Barrie Gilbert, fellow, Analog Devices Inc., Beaverton, Oregon. For advancement of high-speed analog microelectronics.

Prakash C. Kapur, Professor Emeritus, Indian Institute of Technology, Kanpur, New Delhi. For the elucidation, quantification, and synthesis of complex mineral-processing systems.

Peter T. Kirstein, professor, Department of Computer Science, University College London, United Kingdom. For contributions to computer networking and for leadership in bringing the Internet to Europe.

Hendrik Van Brussel, professor, Department of Mechanical Engineering, Katholieke Universiteit Leuven, Belgium. For pioneering research in mechatronics and robotics applied to manufacturing and medical surgery, and for designing holonic manufacturing systems.

NAE Newsmakers

Zdeněk P. Bažant, McCormick Institute Professor and W.P. Murphy Professor of Civil Engineering and Materials Science at Northwestern University, was awarded the **Nadai Medal** of the American Society of Mechanical Engineers (ASME) at the Annual Convention in Boston, Massachusetts, on November 4. Professor Bažant also delivered the **2008 Nadai Lecture**. On November 23 in Vienna, Austria, Dr. Bažant was awarded the **Exner Medal**, the country's highest nongovernmental award in science and engineering. The award ceremony was held in Eschenbach Palace and was followed by a reception at the Hofburg, the imperial palace. On October 11, in Cambridge, Massachusetts, Dr. Bažant was inducted as a **Fellow of the American Academy of Arts and Sciences** (founded in 1780). In September, he was elected a **Foreign Member of the Royal Academy of Engineering of Spain**, his eighth national academy membership.

Karl P. Cohen, retired chief scientist, Nuclear Energy Group, General Electric Company, and **Eli Ruckenstein**, Distinguished Professor of Chemical Engineering, Department of Chemical and Biological Engineering, State University of New York, have been named to the American Institute of Chemical Engineers (AIChE) list of "**50 Chemical Engineers of the Foundation Age**." The list was compiled in conjunction with AIChE's centennial celebration to honor the chemical engineers who "founded the profession and established the discipline in the first half of the century."

Morton M. Denn, Albert Einstein Professor of Science and Engineering, City College of the City University of New York, was awarded the AIChE **2008 Founders Award** on November 18, 2008, at the AIChE annual meeting in Philadelphia. The Founders Award is given to a member of AIChE whose outstanding contributions in the field of chemical engineering have advanced the profession.

Manachem Elimelech, Roberto C. Goizueta Professor, Environmental Engineering Program, Yale University, received the **2008 Lawrence K. Cecil Award** on November 19, 2008, at the AIChE annual meeting in Philadelphia for outstanding contributions to the fields of chemical and environmental engineering.

Richard M. Karp, senior research

scientist, International Computer Science Institute, and professor of computer science, University of California, Berkeley, received the **2008 Kyoto Prize in Advanced Technology** on November 10, 2008. Considered one of the world's leading computer theorists, Dr. Karp was honored for fundamental contributions to the theory of "computational complexity," a way of categorizing problems by their degree of difficulty. His early work in establishing the theory of NP-completeness is used to identify the most difficult-to-solve computing problems and optimize a variety of networks, from those that deliver water, gas, electricity, and data to those that show correlations between gene structures and disease.

The State of Connecticut presented its highest honor for technological achievement, the **Medal of Technology**, to **Tso-Ping Ma**, Raymond John Wean Professor, Department of Electrical Engineering, Yale University, for his pioneering work on semiconductors. The Connecticut Medal of Technology is awarded by the Board of Governors for Higher Education and the Connecticut Academy of Science and Engineering "for scholarship achievement in science and technology."

Van C. Mow, Stanley Dicker Professor and chair, Department of Biomedical Engineering of SEAS, was elected **Associate Fellow of the Academy of Sciences for the Developing World** at its 25th Anniversary Meeting in Trieste, Italy, on November 11, 2008. The academy was founded by a group of distinguished scientists under the leadership of Nobel Laureate in physics, Abdus Salam of Pakistan, and was officially launched by the Secretary General of the United Nations as the Third World Academy of Sciences (TWAS) in 1985. Academy fellows and associate fellows are recognized as among the most distinguished scientists in the world. Professor Mow was elected to TWAS for his nearly 30 years of continuous efforts to build the newly evolving biomedical engineering discipline in China, Taiwan, Hong Kong, and Thailand.

Steven Wallach, advisor, Centerpoint Ventures Partners, was presented with the **Seymour Cray Award** by the IEEE Computer Society Board of Governors. The award is given each year to individuals whose innovative contributions to high-performance computing systems exemplify the creative spirit demonstrated by the late Seymour Cray. Mr. Wallace accepted the award on November 20, 2008, in Austin, Texas. He was cited for his "contribution to high-performance computing through design of innovative vector and parallel computing systems, notably the Convex mini-supercomputer series, a distinguished industrial career, and acts of public service."

Report of the Foreign Secretary

George Bugliarello

On November 17–19, 2008, the annual Japan-America Frontiers of Engineering (JAFOE) Symposium was held in Kobe, Japan, co-sponsored by the Engineering Academy of Japan (EAJ), the Japan Science and Technology Agency, and NAE. Dr. **Tsuneo Nakahara**, president of EAJ, **Lance Davis**, NAE executive officer, and I welcomed the participants. NAE was also represented by Janet Hunziker, head of the NAE Frontiers of Engineering Program. Co-chairs of the symposium were Dr. Kohei Ito of Keio University and NAE member **Arup K. Chakraborty** of the Massachusetts Institute of Technology.

The four sessions of the symposium (with two speakers from Japan and two from the United States in each session and ample time for discussion) were (1) Advances in Automation and Instrumentation for Biotechnology and Health Care; (2) The Future of Sequence Modeling: A Peek into Modern Speech/Language Technology; (3) Alternative Energy; and (4) Advanced Sensor Technology. The next JAFOE symposium will be held in the United States in the fall of 2009.

The 2008 Pan American Federation of Engineering Societies (UPADI) Convention was held jointly with the World Federation of Engineering Organizations (WFEO) in Brasilia on November 29–December 2, 2008. NAE member General **Henry Hatch** (U.S. Army Corps of Engineers, ret.)

participated, and I was invited to give a talk on megacities.

Earlier in November, I attended the annual meeting of the American Society of Civil Engineers in Pittsburgh, held in conjunction with the WFEO. During the international program, a panel on the role of engineers in responding to climate change, which I was asked to moderate, focused on necessary adaptations to climate change, rather than mitigation measures.

The Engineering Academy of Japan has invited NAE to participate in a workshop in March on energy generation, energy saving, recycling, and eco-society. NAE will be represented at the workshop by **Larry Papay**.

Our dialogue continues with Acatech, the newly reorganized German engineering academy. Discussions have been focused on collaborations that will benefit both academies.

Respectfully submitted,

2008 Japan-America Frontiers of Engineering Symposium Held in Kobe, Japan

Participants at the 2008 Japan-America Frontiers of Engineering Symposium in Kobe, Japan.

On November 17–19, 2008, the eighth Japan-America Frontiers of Engineering (JAFOE) Symposium was held at the Kobe International Conference Center in Kobe, Japan. Approximately 60 engineers—30 from each country—attended, with additional representation from the Japan Science and Technology Corporation and the Engineering Academy of Japan—NAE's partners in this program.

The four sessions at this year's symposium were (1) Advances in Automation and Instrumentation for Biotechnology and Health Care, (2) The Future of Sequence Modeling: A Peek into Modern Speech/Language Technology, (3) Alternative Energy, and (4) Advanced Sensor Technology. Presentations given by two Japanese and two Americans in each of the four areas covered feedback control at small scales for biology and medial applications, modeling of differences between spoken language and written language for automatic speech transcription, technical challenges to protecting wind turbines from lightning, and next-generation global environmental sensors.

The Thursday evening dinner speech was given by Dr. Masayuki Nagata, managing executive director, Japan Synchrotron Radiation Research Institute, who provided an overview of the facility that participants toured the next day. Other highlights included a poster session on the first afternoon, during which all participants had an opportunity to describe their research, and a tour of Spring-8, the largest third-generation synchrotron radiation facility in the world. Spring-8 is used for materials analysis, biochemical protein characterization, and other experiments. The tour was followed by a traditional Japanese dinner at a restaurant with a beautiful view of Himeji Castle, a Japanese National Cultural Treasure and the most visited castle in Japan.

Arup Chakraborty, Robert T. Haslam Professor of Chemical Engineering at the Massachusetts Institute of Technology, and Kohei Itoh, professor in the Department of Applied Physics and Physico-Informatics

Poster sessions provide an opportunity for participants to share their research and technical work with each other.

at Keio University, co-chaired the organizing committee and the symposium. Dr. Chakraborty will continue as U.S. co-chair for the 2009 JAFOE Symposium, which will be held November 9–11, 2009, at the National Academies Beckman Center in Irvine, California. The session topics for that meeting will be breakthrough technologies in brain science, modeling global climate change, novel materials for industrial applications, and state-of-the-art technologies for knowledge management.

Funding for the 2008 JAFOE Symposium was provided by the Japan Science and Technology Agency, U.S. National Science Foundation, U.S. Office of Naval Research Global, U.S. Army Research Office, and the Grainger Foundation.

For information about any of the FOE symposia or to nominate an outstanding engineer to participate in a future Frontiers meeting, contact Janet Hunziker at the NAE Program Office at (202) 334-1571 or by e-mail at *jhunziker@nae.edu*.

Workshop on Ethics Education

The NAE Center for Engineering, Ethics, and Society (CEES) sponsored a workshop on "Ethics Education and Scientific and Engineering Research: What's Been Learned? What Should Be Done?" at the Keck Building on August 25–26, 2008. An ad hoc workshop planning committee helped develop the agenda and nominate participants for the workshop. The committee members were **John Ahearne**, NAE member and chair of the CEES advisory group; University of California-Irvine biologist and NAS member Francisco Ayala; astronomer Kathleen Flint, director of the Bring RCR Home Project of the National Postdoctoral Association; political scientist Mark Frankel, director of the Scientific Freedom, Responsibility and Law Program of the American Association for the Advancement of Science; and psychologist Felice Levine, executive director of the American Educational Research Association.

Twenty-five people chosen by the planning committee and a number of National Science Foundation (NSF) observers attended the meeting. Four sessions were held on the first day of the workshop: I. Needs and Issues for Ethics Education in Scientific and Engineering Research; II. Pedagogical Methods and Materials; III. Outreach and Assessment; and IV. Review. On the second day, CEES director Rachelle Hollander chaired a group discussion on next steps.

The following themes emerged from the workshop presentations and discussions:

1. **Context matters.** Societal rewards and the larger societal environment shape behaviors of organizations and individuals in ethically desirable and undesirable ways. Academic administrations that provide wide-ranging, cross-institution programs can encourage and reward ethically appropriate behaviors, particularly in research settings.
2. **Learning matters.** Successful ethics education generally requires obligatory, rather than voluntary, participation by students. Descriptions of successful practices in ethics education and ethics mentoring should be collected and made available to science and engineering communities in academia, government, and the private sector. In addition, efforts should be made to engage employers of scientists and engineers in ethics education programs.
3. **Program criteria.** A standalone, online program for

students, post-docs, and faculty taken on a "pass/fail" basis (with or without grading) does not provide an adequate introduction, much less practical experience, for dealing with the ethical issues that inevitably arise in academic and professional life. However, web-based resources that are adequately maintained and part of a broader program can be very useful. Efforts should be made to identify and classify online resources and tool kits to assist academic institutions, professional associations and societies, principal investigators and faculty, employers, and individuals to develop and implement effective ethics programs and projects.

4. **Interactivity matters.** Students have demonstrated a facility and interest in using online resources in which they can participate and websites that can be individualized to meet their needs. Online resources designed for students should take advantage of their affinity for new media and provide accessible, engaging interfaces. To maintain student interest, material must be updated to reflect changing issues and circumstances.

5. **Mentoring.** Not all types of mentoring activities result in ethical outcomes. Institutions and principal investigators should identify the ways research scientists and faculty or administrators responsible for ethics education can work together on mentoring postdoctoral fellows and graduate students at the dissertation level.

6. **Evaluation.** Efforts to evaluate ethics education for scientific and engineering research and practice are just beginning. At this point, efforts should be focused on developing evaluation criteria for individual and institutional measures of ethics education in scientific and engineering curricula.

7. **Social responsibility and responsible conduct of research.** Ethics education should prepare students to engage in the responsible conduct of research based on standards of practice appropriate to specific fields and professions. Institutions and federal agencies that support ethics education should encourage and reward programs that develop creative approaches incorporating a broad view of the interactions of science, engineering, and technology in society and their ethical implications.

Funding for the workshop was provided by the National Science Foundation. Advice and support for the workshop were provided by the National Research Council Division of Policy and Global Affairs and Committee on Science, Engineering, and Public Policy. The agenda and list of participants, as well as materials from the presentations and discussions, are available at *www.nae.edu/ethicscenter*. A workshop summary will be published and posted online later this year.

Mirzayan Fellows Join NAE Program Office

Melissa McCartney

Joel Baumgart

Ryan Davison

Melissa McCartney recently completed her postdoctoral work in the Department of Neurology at the Children's Hospital of Philadelphia, where she studied network dynamics in the hippocampus as it relates to the generation of epileptic seizures. She was also involved in an after-school science and math program through the Philadelphia Public Schools. In 2006, she completed her Ph.D. in neuroscience at George Washington University, where her research consisted of a pharmacological and biophysical characterization of the GABAA receptor epsilon subunit. In her spare time, she enjoys swimming, running, and camping; she also has a weakness for karaoke.

During her fellowship, Melissa is working on the NAE *EngineerGirl!* website and with the Committee on Capitalizing on the Diversity of the Science and Engineering Workforce in Industry in the Policy and Governmental Affairs Division of the National Research Council. She hopes the insights she gains as a Mirzayan fellow will be of help in her continuing efforts to improve science education at all levels and to promote science through public policy.

Joel Baumgart received his Ph.D. in neuroscience from the University of Virginia in 2008; he earned his B.S. in biochemistry and B.A. in psychology from the University of Missouri. His doctoral research, which was focused on the biophysical properties of voltage-gated calcium channels, was supported by an Epilepsy Foundation predoctoral fellowship and a Sigma Xi Grant-In-Aid of Research. In his free time, he enjoys reading, cooking, and playing soccer.

During his fellowship at NAE, Joel is hoping to expand his perspective by observing and participating in the process of science policy and analysis. He is working with the Center for Engineering Ethics and Society researching societal and ethical issues associated with engineering research and practice. He hopes the lessons he learns as a Mirzayan fellow will serve him well in his future career in academia.

Ryan Davison earned a Ph.D. in behavioral neuroscience from the University of Alabama at Birmingham, where his dissertation research investigated whether the visual system receives neural inputs from different oculomotor subsystems during different types of eye movements. Ryan's graduate research implemented a sophisticated form of electrophysiology that allowed for the activity patterns of single neurons in non-anesthetized, behaving primates to be measured. He continued characterizing the visual system as a post-doctoral fellow at the Smith-Kettlewell Eye Research Institute by implanting strain gauges and muscle force transducers in extraocular muscles in order to better understand the relationship between motor neuron firing rates and the contractile forces of muscles. Ryan is most passionate outside of the laboratory sharing his knowledge and enthusiasm for science with others. His non-academic life is dynamic, and he has traveled extensively throughout the Caribbean, Europe, Asia, and the Middle East. He is also a voracious consumer of political information, and enjoys scuba diving, fishing, and playing tennis.

During his fellowship at the Center for the Advancement of Scholarship on Engineering Education (CASEE), Ryan is working on promoting public awareness of engineering education through workshops and public outreach efforts. This will afford him valuable experience about how best to communicate critical scientific issues to different audiences.

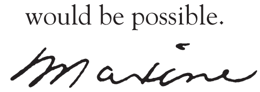
A Message from NAE Vice President Maxine L. Savitz

Maxine L. Savitz

Individuals, universities, organizations, and agencies of all stripes faced unprecedented challenges in 2008. Because of declining endowments, many nonprofit organizations had significant difficulty providing leadership in their areas of focus. NAE was not immune to the financial meltdown, but because of the generous private philanthropy of NAE members, corporations, foundations, and friends, we have continued to address our mission to "promote the technological welfare of the nation." A few key projects and initiatives from 2008 are highlighted below:

- **The William Wulf Campaign for Engineering Excellence.** This campaign was initiated in 2006 to celebrate former NAE president Bill Wulf's leadership and commitment. When the campaign ended in September 2008, NAE had received more than $9.3 million from members, foundations, corporations, and other organizations. The Grainger Foundation donated a gift of $3 million to support the NAE Frontiers of Engineering Program in Bill's honor. This gift has enabled the program to add a series of bilateral meetings with China to complement existing bilateral programs with Germany, Japan, and India. Unrestricted funds received from the Wulf initiative will be used to promulgate other important programs championed by Bill in engineering education, diversity, public understanding, and technological literacy.
- **America's Energy Future.** In the spring 2008 issue of *The Bridge*, I reported that NAE and the National Research Council planned to host an energy summit. This extremely successful event, held in March 2008, initiated a dialogue among national and international scientists, government officials, engineers, and industry experts and resulted in a published booklet highlighting the major topics of discussion. Since then, the America's Energy Future (AEF) Committee and subcommittees have been meeting to complete the Phase 1 reports. The NAE Council Development Committee, which exercised a leadership role in securing financial resources to complete Phase 1, assisted in raising $1.4 million from private corporations and businesses, about 40 percent of the overall funding so far. We anticipate that Phase 1 will be completed in the next several months, and Phase 2 is scheduled to commence immediately thereafter. The NAE Development Committee will continue to play a major role in securing additional financial resources, especially by engaging the corporate community.
- **Frontiers of Engineering Education.** Thanks to a very generous commitment of $700,000 from the O'Donnell Foundation, NAE has begun planning for this new program to promote the engineering profession. Every year, the program will bring together approximately 80 outstanding young engineers from academe, industry, and government to explore innovative engineering education programs, highlight findings from education research in the domains of engineering and science, and share practical guidance on innovative instructional practices.

On behalf of the NAE Council, I wish to thank all of the members, corporations, foundations, government sponsors, organizations, and friends of NAE for this continued commitment, involvement, and generous support, which allows us to proactively serve the technological welfare of our nation. Without this private philanthropic support, none of the programs described above would be possible.



Maxine L. Savitz
NAE Vice President

National Academy of Engineering

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Norman Fortenberry Delivers Keynote Address at Meeting of the Korean Engineering Education Research Center

Front row: Song-Yop Han, Ki-Jun Lee, Norman Fortenberry, Jong-Kee Yeo, and Moon Kyum Kim. Back row: Young Do Kim, Won Lee, Il Moon, Jang Gyu Lee, Dong Joo Song, Kun-Sang Lee, unidentified, and Seung-Ki Lee.

On October 13, 2008, CASEE director Dr. Norman Fortenberry was the keynote speaker at a meeting of the Korean Engineering Education Research Center (KEERC) of the Board of the Accreditation Board on Engineering Education of Korea. Dr. Fortenberry spoke on emerging trends in the United States and other countries in engineering education research, innovation, and practice. Dr. Fortenberry was invited to speak by Dr. Il Moon, KEERC president and professor of chemical engineering at Yonsei University. The event was co-sponsored by the National Academy of Engineering of Korea and the Korean Ministry of Education, Science, and Technology.

Call for Award Nominations

Historically, NAE has recognized outstanding achievements of engineers by awarding five prizes—Founders Award, Arthur M. Bueche Award, Charles Stark Draper Prize, Fritz J. and Dolores H. Russ Prize, and Bernard M. Gordon Prize. To help us continue this historic tradition, we invite you send us your nominations for the 2009–2010 awards.

NAE Awards

The **Founders Award** is presented to an NAE member or foreign associate whose professional, educational, or personal achievements exemplify the ideals and principles of NAE. The **Arthur M. Bueche Award** honors an engineer who has been actively involved in determining U.S. science and technology policy, promoting U.S. technological development, and improving relations among industry, government, and academia. The Founders and Bueche Awards are presented every fall at the NAE Annual Meeting. Recipients receive gold medallions, hand-lettered certificates, and $2,500 cash prizes.

The **Charles Stark Draper Prize** is awarded annually for innovation and the transfer to practice of an advancement in engineering or technology that contributes to the welfare and freedom of humanity. The biennial **Fritz J. and Dolores H. Russ Prize** is awarded in recognition of an engineering achievement that has contributed to the advancement of the human condition. Currently focused on bioengineering, the Russ Prize encourages collaborations between engineering and medical and biological disciplines. The **Bernard M. Gordon Prize for Innovation in Engineering and Technology Education** is given annually to honor educators whose programs have improved the quality of the engineering workforce. The focus is on innovations in curricular design, teaching methods, and technology-enabled learning. The Gordon Prize is shared equally between the recipient(s) and the institution.

The Draper, Russ, and Gordon prizes, which include $500,000 cash awards, gold medallions, and hand-lettered certificates, are presented during National Engineers Week at the NAE Annual Awards Dinner.

Nominators of the winning recipients are also invited to attend.

To Submit a Nomination

Nominations for the **2009 Founders** and **Bueche awards** and the **2010 Draper** and **Gordon prizes** will be accepted through **April 3, 2009**. A list of previous recipients can be found on our website (*www.nae.edu/awards*). Members and foreign associates have received nomination materials by mail. Nonmembers may obtain materials from the NAE Awards Office by phone (202) 334-1628 or e-mail to *awards@nae*.edu. Nomination materials can also be downloaded from our website (*www.nae.edu/awards*).

Nominations should be mailed to NAE Awards, National Academy of Engineering, 500 Fifth Street, N.W. (#1010), Washington, DC 20001, or faxed to (202) 334-2290.

Calendar of Meetings and Events

March 15–21	U.S.-China Cooperation on Electricity from Renewables Joint Committee Meeting Honolulu, Hilo, and Kona, Hawaii
April 2	NAE Regional Meeting University of Illinois Urbana, Illinois
April 3	Deadline for Nomination/ Reference Forms for 2010 Election Renomination Candidates
April 3	Deadline for NAE Awards Nominations
April 14	NAE Regional Meeting Columbia University New York, New York
April 15	NAE Tellers Committee Meeting
April 20–21	Convocation of Professional Engineering Societies
April 23–25	German-American Frontiers of Engineering Symposium Potsdam, Germany
April 29	NAE Regional Meeting Texas A&M University College Station, Texas
May 1	Deadline for Nomination Forms for 2010 Election of New Candidates
May 7–8	NAE Council Meeting
June 5	Deadline for Reference Forms for New Nominations for members and foreign associates
June 17	NAE Finance Budget Committee conference call
June 25–26	Faculty as Academic Change Agents Chicago, Illinois

All meetings are held in the Academies Building, Washington, D.C., unless otherwise noted. For information about regional meetings, please contact Sonja Atkinson at *satkinso@nae.edu* or (202) 334-3677.

In Memoriam

GERARD F. FOX, 85, retired partner, Howard Needles Tammen and Bergendoff, and consulting structural engineer, died on December 12, 2008. Mr. Fox was elected to NAE in 1976 "for contributions in structural theory with innovative elements of construction practice in building bridges."

JAMES GILLIN, 83, retired president, MSD Agvet Division, Merck & Co. Inc., died on December 8, 2008. Dr. Gillin was elected to NAE in 1991 "for unique creativity and engineering of manufacturing processes for pharmaceuticals, and for outstanding management of technology."

JOHN B. GUNN, 80, retired fellow, IBM Corporation, died on December 2, 2008. Mr. Gunn was elected a foreign associate of NAE in 1978 "for the discovery of the Gunn effect, which made possible a simple and reliable solid-state microwave power source."

GRANT L. HANSEN, 86, retired vice president, System Development Corporation, died on October 8, 2008. Dr. Hansen was elected to NAE in 1977 "for contributions to and engineering management of major missile programs."

GEORGE W. HOUSNER, 97, Carl F. Braun Professor of Engineering Emeritus, California Institute of Technology, died on November 10, 2008. Dr. Housner was elected to NAE in 1965 as an "eminent authority on earthquake engineering."

AMOS E. JOEL JR., 90, retired switching consultant, Bell Laboratories, Lucent Technologies, died on October 25, 2008. Mr. Joel was elected to NAE in 1981 "for inventions and contributions to switching system developments for the nationwide public telecommunications network."

DONALD J. JORDAN, 92, retired engineering manager, Pratt & Whitney Aircraft, died on November 10, 2008. Mr. Jordan was elected to NAE in 1976 "for design contributions to jet engines that now power many of the world's transport and military aircraft."

ROGER P. KAMBOUR, 76, retired manager, Polymer Studies Unit, GE Corporate Research and Development, died on December 20, 2008. Dr. Kambour was elected to NAE in 1992 "for pioneering investigations of the structure of crazes in glassy polymers and discovery of their importance in polymer fracture."

ARTHUR R. KANTROWITZ, 95, professor of engineering, Thayer School of Engineering, Dartmouth College, died on November 29, 2008. Dr. Kantrowitz was elected to NAE in 1977 "for leadership in the fields of gas dynamics, magnetohydrodynamics, and bioengineering."

WILLIAM E. LEONHARD, 93, retired chairman, president, and CEO, Parsons Corporation, died on November 11, 2008. Mr. Leonhard was elected to NAE in 1982 "for outstanding engineering achievements and exceptional technical leadership in innovative engineering accomplishments throughout the world."

ALBERT RHOADES MARSCHALL, 87, U.S. Navy, retired, died on November 18, 2008. Rear Admiral Marschall was elected to NAE in 1990 "for outstanding management, stressing highly professional leadership in all phases of vital large-scale worldwide facilities programs."

DAVID MIDDLETON, 88, independent consultant, communication physics and applied mathematics, died on November 16, 2008. Dr. Middleton was elected to NAE in 1998 "for statistical communication theory and applications."

JAMES H. POMERENE, 88, retired fellow, IBM Thomas J. Watson Research Center, died on December 7, 2008. Mr. Pomerene was elected to NAE in 1988 "for contributions to the development of computer organization, including pipelining, reliable main memory, and memory hierarchies."

ROBERT PRICE, 79, private consultant, died on December 3, 2008. Dr. Price was elected to NAE in 1985 "for pioneering achievements in applying statistical communication theory to radio communication, radar astronomy, and magnetic recording."

ROY ROWE, 79, retired consultant, died on December 18, 2008. Dr. Rowe was elected a foreign associate of NAE in 1980 "for construction research and development, including its practical application, in design and construction of bridges."

CHARLES M. WOLFE, 72, Professor Emeritus of Electrical Engineering, Washington University, died on October 18, 2008. Dr. Wolfe was elected to NAE in 1991 "for fundamental achievements in the synthesis and characterization of ultrapure III-V semiconductors."

Publications of Interest

The following reports have been published recently by the National Academy of Engineering or the National Research Council. Unless otherwise noted, all publications are for sale (prepaid) from the National Academies Press (NAP), 500 Fifth Street, N.W., Lockbox 285, Washington, DC 20055. For more information or to place an order, contact NAP online at <*http://www.nap.edu*> or by phone at (888) 624-8373. *(Note: Prices quoted are subject to change without notice. Online orders receive a 20 percent discount. Please add $4.50 for shipping and handling for the first book and $0.95 for each additional book. Add applicable sales tax or GST if you live in CA, DC, FL, MD, MO, TX, or Canada.)*

Adolescent Health Services: Missing Opportunities. Missed opportunities for disease prevention and health promotion are two major problems with U.S. health services for adolescents, which are not designed to help adolescents develop healthy routines, behaviors, and relationships. Although most adolescents are thriving, many have difficulty accessing necessary services; some engage in risky behaviors that can jeopardize their health and contribute to poor health outcomes in adulthood. In this new report, a committee of experts discusses the health status of adolescents and reviews the separate, uncoordinated programs and services delivered in multiple public and private health care settings to young people during this stage of their lives. The report provides guidance for administrators in public and private health care agencies, health care workers, guidance counselors, parents, school administrators, and policy makers on designing and investing in an improved, integrated health system for adolescents.

NAE member **Vinod K. Sahney**, senior vice president and chief strategy officer, Corporate Strategy, Planning, and Business Development, Blue Cross and Blue Shield of Massachusetts, was a member of the study committee. Hardcover, $51.95.

An Assessment of the SBIR Program. The Small Business Innovation Research (SBIR) Program allocates 2.5 percent of 11 federal agencies' extramural research and development (R&D) budgets to fund R&D projects by small businesses. The program awards grants, on a competitive basis, of approximately $2 billion per year. At the request of Congress, the National Academies conducted a comprehensive study to determine if the program has stimulated technological innovation and if the work done by small businesses meets federal R&D needs. Drawing substantially on new data, this report provides a comprehensive overview of the SBIR Program at the U.S. Department of Defense, National Institutes of Health, National Science Foundation, U.S. Department of Energy, and National Aeronautics and Space Agency (the five agencies that account for 96 percent of program expenditures) and recommends improvements to the program. Individual reviews of the five agencies are also available.

NAE members on the study committee were **Jacques S. Gansler** (chair), vice president for research, professor, and Roger C. Lipitz Chair in Public Policy and Private Enterprise, School of Public Policy, University of Maryland; **Trevor O. Jones**, chairman and CEO, ElectroSonics Medical Inc.; **Duncan T. Moore**, professor, Institute of Optics, University of Rochester; and **Charles R. Trimble**, chairman, U.S. Global Positioning System Industry Council. Hardcover, $79.00.

Understanding Crime Trends: Workshop Report. Changes over time in the levels and patterns of crime have significant consequences, not only for the criminal justice system, but also for other critical policy sectors. Yet the country does not have timely information or comprehensive research on crime trends. In April 2007, the National Research Council (NRC) held a two-day workshop to address substantive and methodological issues underlying the study of crime trends and to lay the groundwork for a proposed multiyear NRC panel study of these issues. Six papers commissioned from leading researchers were discussed at the workshop, which was attended by experts in sociology, criminology, law, economics, and statistics. The authors revised their papers based on discussants' comments, and the papers were then reviewed by outside experts. The six final papers are published in this volume.

NAE member **Alfred Blumstein**, University Professor and J. Erik

Jonsson Professor of Urban Systems and Operations Research, H. John Heinz III School of Public Policy and Management, Carnegie Mellon University, was a member of the study committee. Paper, $53.75.

Severe Space Weather Events—Understanding Societal and Economic Impacts: Workshop Report. The adverse effects of extreme space weather on modern technology—such as power outages, high-frequency communication blackouts, and spacecraft anomalies—have been well documented, and the physical processes of space weather are generally well understood. However, the potential social and economic impacts of disruptions in critical technological systems have not been studied in depth. The workshop summarized in this volume was a first step toward determining the socioeconomic impacts of extreme space weather and addressing space-weather risk assessment and management. In May 2008, representatives of industry, government, and academia came together for a public workshop to discuss direct and collateral effects of space-weather events, the current state of the space-weather services infrastructure, the need for space-weather data and services, and the effects of the development of future technologies on our vulnerabilities to space weather. The workshop concluded with a discussion to identify the most important unexplored or underexplored topics for space-weather risk management.

NAE member **Joseph B. Reagan**, retired vice president and general manager, Lockheed Martin Missiles and Space Company, was a member of the study committee. Paper, $35.00.

Maritime Security Partnerships. No single navy or nation can provide maritime security, which requires capabilities for the direct confrontation of pirates, drug traffickers, and illegal immigrants. A former Chief of Naval Operations called for a collaborative international approach, initially called the "1,000-ship Navy," which would require that U.S. naval forces partner with multinational, federal, state, local, and private-sector forces to ensure freedom of navigation, the unimpeded flow of commerce, and the protection of ocean resources. This report describes the technical and operational implications of the "1,000-ship Navy" at four levels of cooperation: (1) U.S. Navy, Coast Guard, and merchant shipping only; (2) U.S. naval and maritime assets in cooperation with treaty and alliance partners or analogous arrangements; (3) U.S. naval and maritime assets with ad hoc coalitions; and (4) U.S. naval and maritime assets with partners that may be friendly but could potentially be hostile, for certain operations, such as deterring piracy and other criminal activities.

NAE members on the study committee were **David A. Whelan** (co-chair), vice president, GM-Deputy Advanced Systems, and chief scientist, IDS, Boeing Company; **Thom J. Hodgson**, Distinguished University Professor, Industrial and Systems Engineering Department, North Carolina State University; and **John P. Stenbit**, retired executive vice president, TRW Inc. Paper, $51.75.

Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks. This new report from the National Research Council concludes that an integrated nationwide meteorological and chemical weather network that measures atmospheric conditions at various heights and scales is badly needed. In addition to weather observations, such a network could track the dispersion of biological and nuclear contaminants from industrial accidents; monitor smoke from wildfires; provide high-resolution weather information for air and water transportation, water management, and food production; and support regional climate monitoring.

NAE member **Margaret A. LeMone**, senior scientist, National Center for Atmospheric Research, was a member of the study committee. Paper, $49.00.

Review of NASA's Exploration Technology Development Program: An Interim Report. To meet the objectives of the Vision for Space Exploration (VSE) initiative, the National Aeronautics and Space Administration (NASA) must develop a wide array of enabling technologies. To oversee and coordinate that development, NASA established the Exploration Technology Development Program (ETDP), which currently has 22 projects under way. In the report that accompanied the House-passed version of the FY2007 Appropriations Bill, NASA was directed to request an independent assessment of ETDP by the National Research Council. This interim report provides assessments of all 22 projects in terms of quality, the effectiveness of research, and the relevance to VSE goals. The authoring committee also provides preliminary discussions of cross-cutting issues, which are explored in more detail in the final report.

NAE members on the study committee were **Edward F. Crawley** (co-chair), executive director, CMI, and professor, Aeronautics and Astronautics, Massachusetts Institute of Technology; **Bonnie J. Dunbar** (co-chair), president and CEO, Seattle Museum of Flight; and **John R. Howell**, Ernest Cockrell Jr. Memorial Chair, Department of Mechanical Engineering, University of Texas. Paper, $21.00.

A Constrained Space Exploration Technology Program: A Review of NASA's Exploration Technology Development Program. A major objective of the Vision for Space Exploration (VSE) announced in January 2004, was that the National Aeronautics and Space Administration (NASA) "extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations." NASA's Exploration Technology Development Program (ETDP) is designed to support, develop, and ultimately provide the technologies necessary to meet VSE goals. This review of ETDP finds that the program is making progress toward its stated goals but is operating under significant constraints that have limited its ability to meet them. The constraints include still evolving requirements for the Constellation Program, budget limitations, an aggressive time scale for the delivery of early technologies, and NASA's desire to continue to employ its entire workforce.

NAE members **Edward F. Crawley**, executive director, CMI, and professor of aeronautics and astronautics, Massachusetts Institute of Technology; and **Bonnie J. Dunbar**, president and CEO, Seattle Museum of Flight, were co-chairs of the study committee. NAE member **John R. Howell**, Ernest Cockrell Jr. Memorial Chair, Department of Mechanical Engineering, University of Texas at Austin, was also a member of the study committee. Paper, $36.75.

U.S. Conventional Prompt Global Strike: Issues for 2008 and Beyond. Conventional prompt global strike (CPGS), a military option under consideration by the U.S. Department of Defense, would provide an option for a quick, non-nuclear response to dangerous threats in some scenarios. This National Research Council report includes an analysis of proposed CPGS systems and an evaluation of their potential place in the overall U.S. defense landscape. The report provides near-term, mid-term, and long-term recommendations for the development of CPGS systems based on their capabilities.

NAE members on the study committee were **John S. Foster Jr.**, retired vice president, science and technology, Northrop Grumman Space Technology; **Richard L. Garwin**, IBM Fellow Emeritus, IBM Thomas J. Watson Research Center; **L. David Montague**, president, L. David Montague Associates, and retired president, Missile Systems Division, Lockheed Martin Missiles and Space; **John P. Stenbit**, retired executive vice president, TRW Inc.; and **Robert H. Wertheim**, rear admiral, U.S. Navy (retired), and consultant, San Diego, California. Paper $51.00.

Progress Toward Restoring the Everglades: The Second Biennial Review, 2008. This is the second biennial evaluation of progress in the Comprehensive Everglades Restoration Plan (CERP), a multibillion-dollar effort to restore historical water flows to the Everglades and return the ecosystem closer to its natural state. Launched in 2000 by the U.S. Army Corps of Engineers and the South Florida Water Management District, CERP includes approximately 50 major projects to be completed in the next several decades. The review committee concludes that budgeting, planning, and procedural problems continue to interfere with the implementation of CERP, which so far has made scant progress toward achieving its goals. To date, CERP has not completed a single project, and future progress is likely to be limited by constraints on funding and cumbersome authorization mechanisms. The review committee recommends that managers focus on resolving complex planning issues and then move forward with the projects that are most important to restoring the natural ecosystem.

NAE members **Charles T. Driscoll Jr.**, University Professor, Syracuse University, and **Jean-Yves Parlange**, professor, Cornell University, were members of the study committee. Paper, $65.75.

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