Personal Motion Technologies for Healthy Independent Living

Bethesda, Maryland
June 22–24, 2010

WORKSHOP SUMMARY

Workshop Sponsors:

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LIST OF ACRONYMS AND ABBREVIATIONS

AD	Alzheimer's disease
ADL	activity of daily living
AEDA	Alzheimer's Early Detection Alliance
CAST	Center for Aging Services Technology
CMS	Centers for Medicare and Medicaid Services
EMR	electronic medical record
FDA	U.S. Food and Drug Administration
GPS	Global Positioning System
HIPAA	Health Insurance Portability and Accountability Act
iADL	independent activity of daily living
MCI	mild cognitive impairment
NIA	National Institute on Aging
NIBIB	National Institute of Biomedical Imaging and Bioengineering
NIDRR	National Institute of Disability and Rehabilitation Research
NIST	National Institute of Standards and Technology
NSF	National Science Foundation
SHIMMER	Sensing Health with Intelligence, Modularity, Mobility, and Experimental Reusability
TRIL Centre	Technology Research for Independent Living Centre
VA	U.S. Department of Veterans Affairs

TABLE OF CONTENTS

National Institute on Aging
National Institute of Biomedical Imaging and Bioengineering

Workshop on Personal Motion Technologies for Healthy Independent Living

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INTRODUCTION

The United States population is aging, with the first of the baby boomer cohort turning 65 in 2011. As individuals age, they develop problems with personal motion and disabilities that hinder their ability to live independently, and they eventually move into assisted living facilities or skilled nursing homes. At present there are no good ways to monitor and identify problems, other than personal or caregiver reports. Collaboration between the engineering and geriatric worlds can thus yield new approaches for daily monitoring and ways to allow older adults to live independently for a longer period of time. There is also a role for behavioral science in identifying how these approaches will be used in a targeted population, thus increasing the chances that effective approaches will be adopted. The National Institute on Aging (NIA) and the National Institute of Biomedical Imaging and Bioengineering (NIBIB) have long been interested in these types of collaborations.

On June 23–24, 2010, NIA and NIBIB held a workshop to discuss technologies that might enable older adults to live independently longer. The workshop brought together 60 clinicians, academic researchers, engineers, patient advocates, caregivers, members of the public, NIH staff, and representatives from the Centers for Medicare and Medicaid Services, the Food and Drug Administration, the National Science Foundation, and the Department of Veterans Affairs. The workshop was videocast live to 80 viewers on June 23 and 40 viewers on June 24.[1] (See Appendices 1-3 for biographical sketches of presenters and the fins list of participants and final workshop agenda.)

Workshop participants discussed the use of these technologies in identifying early indicators of disease or adverse events, monitoring daily activities, coping with impairment, managing mild cognitive impairment, rehabilitation and exercise, and caregiver support. Six workshop sessions followed opening remarks by Dr. Marie Bernard, Deputy Director of NIA, and Dr. Belinda Seto, Deputy Director of NIBIB, and an introduction and overview by Dr. Jeffrey Kaye, of the Oregon Health and Science University. In each session, workshop participants heard presentations and discussed clinical needs, the health impact of addressing these needs, state-of-the-art technologies, and challenges and barriers to adopting these technologies. The workshop concluded with a general discussion.

[1] The videocast is archived at http://videocast.nih.gov/Summary.asp?File=15989 (Day 1) and http://videocast.nih.gov/Summary.asp?File=15992 (Day 2), and includes a link to the NIBIB website with the final agenda, list of participants, and speaker biosketches: http://www.nibib.nih.gov/NewsEvents/SympReports/2010June22

Several themes emerged from discussions throughout the workshop:

- Users should be involved in research and development to increase the likelihood that technologies will be adopted.
- Independent living should not rely on just one technology; instead it should integrate several types into a system that also includes clinical measures.
- Privacy is a key concern, but seniors are willing to sacrifice some privacy for an effective technology that keeps them in their homes. However, they do want control over who receives their data.
- Multilevel and multiscale models that can account for changes in the environment are needed to understand motion in the context of the environment and to design effective systems.
- Implementation and adoption of a technology will be easier if clinicians, patients, and families understand the technology's clinical value.
- More real-world testing is needed.
- Funding agencies and the public should understand that technologies will undergo several iterations between laboratory development and implementation in the community.
- More work is needed to detect falls and to understand risks and causes.
- Clinicians should encourage more physical activity, rather than exercise, as many people are active without participating in formal exercise programs.
- Knowledge must be derived from the data generated by personal motion technologies. Developers and clinicians should work together to identify which data are needed and to develop the simplest solutions possible.
- Accessibility and usability by persons with disabilities should be considered a core value, similar to efficacy and safety.

OVERVIEW: PERSONAL MOTION AND ACTIVITY TECHNOLOGIES IN HEALTHY INDEPENDENT LIVING

Jeffrey Kaye, MD, Oregon Health and Science University

The U.S. population is aging and will have chronic illnesses that account for a disproportionate amount of resources. In addition, the nation is facing shortages in primary care providers and nurses, and both professional and informal caregivers are limited in their ability to fully address the needs of aging individuals. Clinical practice is moving away from traditional silo- and procedure-based reactive health care toward proactive care that is centered on the person, the home, and community-coordinated models. This shift has been codified in recent Congressional legislation and in a digital health revolution that includes electronic medical records (EMRs), telemedicine, ambient assisted living, and information-based comparative effectiveness studies. In light of these challenges and changes, personal motion and activity technologies should be considered as a way to improve the health and independence of the aging population.

Health care and medicine rely on the ability to identify relative differences. Traditionally, this has involved inferences based on functional and physical assessments at intermittent time points. Measures are performed at the convenience of the clinician or investigator, involve artificial and often burdensome tests, depend heavily on recall or brief snapshots, and assume that observations taken at a visit represent typical function. In addition, variability between tests and between observers is high. Thus, with traditional methods, assessing change with any kind of

precision is difficult, and clinicians have little understanding of what happens at home or what else might be happening in the patient. With the push toward proactive, personalized, and effective care, assessment should move toward real-time, real-world, unobtrusive, and continuous measures.

Personal motion and activity technologies could aid in such measures by providing constant data that allow clinicians to see variability and trends or trajectories, rather than absolute values, and to understand how traditional measures are affected by daily activities. These technologies might capture rare, irregular, or evanescent events; activities that are difficult for patients to report; and syndromes that evolve slowly over time with poorly marked onset or transitions. In addition, data collected through these technologies, combined with symptoms reported by the patient, could increase the likelihood of early detection.

Technology research and development should therefore account for health considerations and the user: how the technology could assess that person at home or in the community, and how it could be applied to various health problems or needs. At present, technologies are developed and tested first in laboratory or "smart home" settings, then in community studies. However, smart homes are not the real world, particularly with respect to an older person with increasing disability, and community studies cannot be scaled widely. Future development should involve continuous improvement in framing basic and clinical questions and solutions, improvement of technology, careful consideration of scalability, and rapid expansion of the evidence base. A wide array of existing technological platforms, including actigraphy devices, cell phone-based prompters or tracking, and motion/activity, physiological, and localization sensors, are available, and efforts are under way to apply them more widely in a community.

Workshop participants were asked to consider several points:

- Uniqueness and data size are not ends in themselves; thus more data and finer granularity might not be needed. Instead, measures should be scaled to need.
- Basic development, prototyping, and demonstrations must be balanced with practical near- and long-term clinical needs and outcomes.
- Real-world applications and data do not usually conform to theory or prototypes. Thus models require many versions for success.
- One technology does not fit all. The right tool must be matched with the appropriate task.
- More evidence of efficacy and effectiveness is needed. In many cases, the ability of a technology is overstated.
- Many in the community sense the potential of these technologies, but they do not fully understand how the technologies will help them. Technology developers should aim to publish in conventional clinical journals and foster cross-pollination.

Much is known about human biology, thanks to projects such as the Human Genome Project. With the array of available technological platforms, one could envision a Human Activity Project, which would use personal motion/activity technologies to describe real-time activity, change the fundamental understanding of basic human activity, and aid in improving efforts at intervention and maintaining health.

SESSION 1: DETECTING PERSONAL MOTIONS AND BEHAVIORS AS EARLY INDICATORS OF DISEASE OR ADVERSE EVENT ONSET

Moderator: William Heetderks, MD, PhD, National Institute of Biomedical Imaging and Bioengineering

Mobile Technologies in Clinical Care

George A. Taler, MD, Washington Hospital Center

The adoption of motion technologies depends on their value to clinicians and patients. Clinicians see these technologies in two ways. Diagnostic technologies measure behavioral motion, such as gait, sleep, abnormal movement, and aberrant behaviors, as well as physiological motion such as respiratory patterns, gastrointestinal motility, and urinary pathology. Monitoring technologies are used in acute-phase settings such as the intensive care unit (ICU), transition from hospital to the community, or rehabilitation, all of which require intensive monitoring and a large amount of data. They also can be used in longitudinal phases, with continual or episodic surveillance and responses triggered by changes in position, location, or physiological measures. If researchers and developers can identify the categories in which their technologies fit best, clinicians will be able to see the technologies' value.

The value of a technology also depends on how it is implemented. At present, 5 percent of the population uses 50 percent of all health care resources, and two-thirds of the population use less than 5 percent of these resources. People aged 85 years or older form the fastest-growing cohort, and because there are fewer children in the population, more attention is paid to their activity and health. Thus technologies should be targeted toward the right group of people, for example people with multiple chronic illnesses or chronic illness and functional impairment, and they should look at both ends of the lifespan. Implementation also will have to address privacy concerns, as well as questions of who pays for a technology. Moreover, changes in health care policy will affect how new technologies are implemented. Health care is moving from a fee-for-service model, in which clinicians are paid based on what they do, toward a paradigm where clinicians are paid based on outcomes. Four initiatives are under way:

- Transitional care programs, which are driven by nurse practitioners and aimed toward patients who are more likely to be readmitted to the hospital.
- Patient-centered medical homes, which help physicians manage chronic illnesses.
- Accountable-care organizations, which are constellations of medical homes covering populations of 50,000 to 100,000 people.
- Independence at home, which provides high-tech intervention in the home for the 5 percent to 10 percent of the population who cost the most.

Discussion Points

It is difficult to understand how clinicians will know the value of what they measure. For example, recent studies have shown that some measures taken at home are more important than those taken in the clinic. Health cost savings is one clear value.

Alzheimer's Disease (AD)

Nancy Cullen, Alzheimer's Association

More than 5 million Americans live with AD, and the baby boomer generation is entering the age of greatest risk. One of eight people older than 65 and one of every two people older than 85 have AD, and the majority of them live in the community and want to live safely at home. In addition, more than 11 million people are providing care for patients with AD, dedicating more than 12.5 billion hours of unpaid care. Thus personal motion and other technologies should aid not only paid professionals, but also families trying to keep their loved ones at home as long as possible. The Alzheimer's Association reaffirms the patient-centered approach and has implemented several initiatives.

One, the Alzheimer's Early Detection Alliance (AEDA), addresses the challenges of detecting and diagnosing AD by giving families tools to begin discussions with physicians at an earlier time. AEDA offers a web page listing the 10 warning signs, provides families with free access to online tools, and communicates with employers and the public about these signs. The Alzheimer's Association also has involved AD patients in creating principles for dignified diagnosis. This effort highlights the importance of involving users in the research to increase adoption and improvement of a technology. In addition, the Alzheimer's Association has partnered with Microsoft and Accenture to conduct a feasibility study on technology in terms of safety and security, health and wellness, and education and planning. This study has specifically focused on the triggers, needs, and behaviors associated with wandering. Based on this study and on discussions with child caregivers, the Association has built the Aging Safely vision, which emphasizes increased independence, proactive care, and efficient caregiving, and a device- and network-neutral platform called Comfort Zone.

Ethnic and cultural issues affect the implementation of a technology. For example, a special report about race and ethnicity notes that the Hispanic and African American community are more affected by AD, but members of these communities are more reluctant to visit the doctor and seek diagnosis. The symptoms of AD are considered to be a part of the normal aging process, and many caregivers do not seek assistance until other family members confirm their suspicions. The Alzheimer's Association is exploring ways to use technology to enhance care, as well as ways to help patients and families accept these technologies.

Some principles have emerged from these efforts:

- Both individuals in the home and those in residential facilities want enhanced quality of care.
- Patients and their families want choice, education, and both low- and high-tech solutions to help them find approaches that best fit them.
- Coming up with only one solution for a problem is limiting. A safe home should integrate many tools and technologies.
- Education is important; patients and their families need help in identifying their needs, and they should know the limitations of each technology.

Discussion Points

- Many individuals in the community are interested in testing new technologies, but it is not clear whether technologies are at a point where they can be tested or how they will be monitored and managed.
- Technologies do not have to be perfect for a community to test them. In light of the difficulties patients and caregivers face, "good enough" is fine.
- Homing in on wandering was somewhat difficult because of a desire to maintain dignity and a large amount of denial that a person will wander. The Association is working to help families overcome that denial.

Movement as Behavioral Markers of Physical and Cognitive State

Misha Pavel, PhD, Oregon Health and Science University

Personal motion technologies aid in assessing how mobile people are and what they can do, and they can help clinicians make inferences about cognitive and physical states. However, any motion is complex and requires functions at several levels. Technology must accommodate several time scales, from detection of cognitive decline, which is on a scale of years, to acute care, which is on a scale of seconds to minutes. In addition, the goal and ability to use a technology to monitor hundreds of people assumes that the technology is cheap and simple. Personal motion technology will be important to caregivers, who are concerned with actions; coaches, who are concerned with behaviors and function; and clinicians, who are concerned with mechanisms that can be addressed with treatment. Thus research and development of personal motion technologies is a multidisciplinary, multilevel, and multi-scale process, and because of the level of uncertainty, this research must rely on appropriate models to gauge the relationship between motion and other factors.

In one example, raw sensor data must be fused into a home-based assessment platform that will allow inferences and measures of change. Fusion requires synchronization of devices and measures to increase the likelihood that they are measuring the same thing at the same time. This principle is illustrated, for example, by the use of motion sensors to measure walking speed. Such a platform has shown behavior just before and just after a stroke occurred, and it could help in detecting MCI. However, the platform requires algorithms that minimize the number of false positive and false negatives. In another example, a game called On the Flipside uses fine motion, such as typing or use of the computer mouse, to provide insight into cognition. This game has allowed researchers to identify memory trajectories and observe declines in working memory. However, it shows a lot of variability and has not yet been related to neuropsychological tests.

Scalability remains a key challenge in getting technologies into the community, because of the diversity in situations and environment. With respect to cognitive states, models of disease and decline dynamics will be required; thus appropriate neuropsychological markers and phenotypes must be identified. These models must address issues with temporal coherence, synchronization, and decision theoretic approaches with context-aware and real-time utility assessment. Particularly challenging is the need to recognize incongruent or rare events, which has been problematic for machine learning. Models and technologies should allow for data mining in large, heterogeneous datasets, and they should allow the correct data and information to be presented to the right person in an appropriate way.

Discussion Points

- Integration of devices is necessary to monitor understand how well a system is working and how it responds to environmental changes.
- Minimizing the intrusiveness of devices is a concern in personal motion technologies. However, individuals might be willing to trade some privacy for devices that prove effective.

Continuous Monitoring in the Home

Marjorie Skubic, PhD, University of Missouri, Columbia

Dr. Skubic's group has deployed several units using infrared motion sensing and cameras to create motion sensor density maps. These maps can be used to capture activity level and distinguish individuals with active lifestyles from those with sedentary lifestyles. Motion sensor density maps also have allowed researchers to see evidence of cognitive impairment by measuring changes over time. Dr. Skubic and colleagues are also exploring the use of bed-sensing data to derive low-pulse events and restlessness patterns, as a possible way to identify early signs of illness. For example, preliminary retrospective work has shown pattern changes in the time leading to an emergency-room visit.

Dr. Skubic and her colleagues also have used vision to assess fall risk. Visual monitors are used to conduct physical functional assessments based on measures used by physical therapists: walking speed, step time and length, footsteps, gait symmetry, body sway, and sit-to-stand. To address privacy concerns, the group does not use raw images. Instead, it extracts silhouettes or uses a two-camera system to build three-dimensional models called voxel images. Voxel images show good agreement with Vicon technology in assessing velocity and body sway. Footsteps extracted from these images also show good agreement with GAITRite and silhouettes. The voxel technology relies on $100 webcams, making it far less expensive than Vicon or GAITRite.

Throughout the development and testing of this process, Dr. Skubic and colleagues have continued to conduct focus groups and interviews to assess whether the target population will accept the technology. Acceptance is related o need and perceived benefits, and there are few privacy concerns with motion- or bed-sensing. However, older individuals do want control over who has access to their data, and they care about how the technology looks. Most participants like the silhouette imagery and footsteps. They find the silhouettes to be protective of their privacy, but they want the ability to turn that image off. Thus, the technology will require some customization in the amount of control over privacy.

Discussion Points

- The technologies described by Dr. Skubic could be applied to individuals in wheelchairs, assuming other factors captured by motion technology could influence the way they drive their chairs. However, this has not yet been studied.
- Patients were interested in their footsteps because they could see how the images would be used clinically.

Session Discussion Points

- Baseline values must be customized to the individual, and researchers should choose whether to use a rolling baseline measure or take a value when an individual enrolls.
- Variability is important, and monitoring should therefore be done on several scales to distinguish important changes from random ones. Each individual should be used as his or her own control, but what is known about the population is also important when little is known about the individual. Personal motion technologies also should account for changes in environment.

SESSION 2: UBIQUITOUS AND NON-INVASIVE MONITORING OF DAILY ACTIVITIES

Moderator: Zohara Cohen, PhD, National Institute of Biomedical Imaging and Bioengineering

Monitoring and Privacy Issues in Quality-of-Life Technology Applications

Richard Schulz, PhD, University of Pittsburgh

Despite the myriad advantages of personal motion technologies with respect to health and independence, these technologies monitor behavior and collect, store, and share personal health information. Yet in the 2008 AARP *Healthy@Home Survey*, 90 percent of respondents expressed a willingness to sacrifice some privacy to stay at home.

Dr. Schulz and other investigators at the University of Pittsburgh and Carnegie Mellon University assessed privacy concerns in a sample of baby boomers and a sample of older adults. Survey results showed that monitoring toilet behavior and sharing health information with the government and insurance companies were least acceptable to respondents. Sharing information about an individual's driving was acceptable, as long as that sharing was restricted to family members. The acceptability of data depended on how that data was collected: sensor-based data was more accepted, but toileting information overall was least acceptable. There was no difference between baby boomers and older adults in terms of acceptability, but the willingness to give up privacy increased with increasing disability.

When surveys further explored tradeoffs between reduced privacy and independence, respondents generally preferred sensors over video-based approaches. However, there was some willingness to accept video except for in the bedroom and bathroom. These preferences were not affected by the activities of daily living (ADL) in which individuals were assisted by technologies. Level of disability and educational status predicted acceptance of home monitoring.

On the basis of these data, technology should be developed in a way to allow users some control over who receives their data. Anonymization of these technologies is under exploration, but information is lost as technologies are anonymized. More research is needed into demographic and health correlates of acceptance or rejection of privacy tradeoffs, tipping points at which privacy tradeoffs are acceptable, and explicit privacy tradeoffs.

Discussion Point

More real-world testing of monitoring technologies is needed. For example, it is not clear what will happen when these technologies begin to affect medical feedback or access to care. Concerns about this issue are already apparent in patients' unwillingness to have their data shared with insurance companies.

Emerging Medical Models of Care

Gregory J. Hanson, MD, Mayo Clinic

With insufficient numbers of primary care physicians, geriatricians, mid-level providers, and nurses, current models of medical care will become strained as the U.S. population gets older. Families are more fragmented geographically, leading to social and economic isolation of elders. Current home-based care models are limited in scalability, and with a universal desire for independence at home, the types of patients seen in assisted-living facilities and the nursing home today resemble those seen in skilled nursing homes in the past. Older people are heterogeneous in health and functional status, and risk stratification is necessary to ensure that intensive medical services are provided to those who need it. In addition, payment and reimbursement policies are shifting toward episodic payment bundling and accountable care organizations. Thus new models of care are needed.

Emerging medical models of care must accommodate issues unique to elders, including cognitive impairment; hearing and vision loss; reduced mobility, endurance, and dexterity; and social isolation. Older individuals might be less familiar with and even afraid of technology, and some might live in residences with limited technologic capabilities. Yet new care models will rely on technology to enhance the reach of the provider by predicting and identifying changes in clinical status, monitoring for chronic disease goals, and improving communication with and responsiveness by providers. In general, these models will need technology to be mobile, usable by elders and multiple users, and unobtrusive. The technology should allow multi-provider and multi-site monitoring and fit into primary practice, and data should be storable in an EMR. Software that provides decision support and event management or alerts also should be included. The technology should be scalable to hundreds of patients, and it should provide proven cost savings in terms of fewer emergency room visits and hospitalizations.

Clinicians are excited about the potential of activity monitoring and its ability to provide location monitoring and event warning. They also are interested in motor processing, which will be important in identifying and predicting falls and in monitoring gait and effects of multitasking. However, these abilities should be integrated with other items of clinical interest. Such single-source integration could provide simultaneous biometric data, remote communication and diagnostic tools, and patient education.

Discussion Point

Clinicians are likely to adopt targeted technologies that are proven to be effective, despite costs.

myHalo® Health and Fall Alert Monitoring for Aging Seniors and Their Caregivers

Chris Otto, MS, Halo Monitoring, Inc.

Halo Monitoring, Inc., is a private, "aging in place" company that aims to keep people in their homes longer. Although it has begun expanding into round-the-clock health monitoring, the company's primary focus is on falls. Emergency response devices are not effective; in 80 percent of falls, the person who falls is alone and unable to use the alarm. Halo Monitoring provides an alternative in the form of two products, myHalo Clip® and myHalo Complete®, which incorporate automatic fall detection, reminders to wear monitoring devices, proactive alerts, and a web-based dashboard. myHalo Complete® also provided data on heart rate and when the individual is wearing it, and it can be worn all the time. The two devices are discreet and unobtrusive, and they communicate with a home getaway that encrypts information and uploads it to a health server and platform compliant with the Health Insurance Portability and Accountability Act (HIPAA). On the basis of alerts, information can be transmitted to a call center that calls patients, their informal and professional caregivers, and if necessary, emergency services. Informal caregivers can access the web dashboard, which is interactive and easy to use.

The myHalo® devices have been deployed on a modest scale, and they are collecting and amassing a large amount of data, about 3 megabytes per user per day. It should be noted that the data collected is not useful unless it is relevant, timely, and actionable. Thus Halo Monitoring is working with clinicians and providers to determine what information is usable and actionable, such as triggers for intervention or reports of prior events. Halo Monitoring is also working with professional caregivers to pilot a remote caregiver triage interface, which allows caregivers to aggregate data over a population, then decide, based on pre-defined parameters, which individuals might require a call or check-up.

Discussion Points

- Because of finite resources and what can be accomplished from marketing and branding, Halo Monitoring has chosen to focus primarily on older people. However, some myHalo® users are patients with epilepsy, and there is some interest from advocacy groups for blind people. The devices could be used for any condition where falling is a concern.
- Halo Monitoring is working to address issues with false-positives and battery life.
- Athletes represent another market, and other companies already have developed devices targeted toward them. myHalo® devices could be useful here, but Halo Monitoring's has chosen not to expand into that market at this time.

Personal Motion Technology Project Examples

Joseph Paradiso, PhD, Massachusetts Institute of Technology

Sensors and accelerometers are fast becoming a commodity and can be designed into almost any devices such as cell phones or iPods. Caring for the aging population will represent the vanguard in personalized fusion of technologies, but these applications are likely to be used more widely. The examples provided here might appear tangential but could be useful in a variety of settings.

Examples of fused technologies include:

- A shoe that contains several sensors for interactive entertainment. Dancers can create music in real time through their steps, and they can get such information as tilt, shock, rotation, and height of movement.
- An interface integrated into an iPod so that individuals make music as they exercise.
- A wearable biomotion measure that allows researchers to examine how individuals bring their foot up. Such a technology could help identify individuals with Parkinson's disease.
- The use of personal devices to help people move. For example, a metronome can help people walk. Similarly, a device could play rhythmic music to help Parkinson's patients when their walking falters.
- A wearable measure that has been used by baseball players during spring training to capture and store information about performance.
- Disposable wireless sensors that measure motion by jerks and pulses and wake up to capture data when it is needed.
- Wearable, low-power monitors that measure temperature, humidity, and light levels; log continuous motion; and communicate with an infrastructure. Such a device could, for example, build a personalized program for heating and air conditioning based on comfort levels inferred from personal reports during the first 2 weeks of wear.
- Ubiquitous sensor portals that track with privacy protocols in a dynamic way and can remove images or voices of individuals who opt out.

As illustrated by these examples, personal motion technologies can be wearable, cheap, and low power, and they can communicate with infrastructure or individuals' phones. Moreover, privacy concerns about video monitoring can be address with dynamic privacy controls.

Discussion Point

The existence of appropriate infrastructure will be critical to marketplace adoption and deployment of these technologies. In addition, technologies will undergo several adaptations as they make the transition from the laboratory to the community.

Session Discussion Points

- Although it is reasonable that people would have the greatest concerns about privacy in the bathroom and bedroom, these are the places where the risk for falls is highest. The need to balance these concerns can be done technically, but it will require some negotiation with patients, their families, and providers. Trust between patients and health care providers will be key.
- Development of myHalo® devices began with choreographed falls and motion patterns defined based on common fall types and normal ADL. When the devices were deployed in beta and live testing, unanticipated events were noted and addressed in the next iteration.
- A typical myHalo® user has one false-positive a month. However, this is a rather high rate from a clinical perspective and raises concerns about a "car alarm" effect, where alarms are ignored.
- The acceptability of personal motion technologies also might depend on how they are purchased. The current health care model relies on fee for service, which for example pays if

a magnetic resonance image is taken, regardless of the outcome. This could change with a shift to outcome-based payment.

- The U.S. Food and Drug Administration (FDA) will regulate anything that appears to be a medical device. However, this agency does not aim to hinder innovation. It is working with the Federal Communications Commission to explore the proliferation of applications in robotics and wireless systems and better define what a medical device is. FDA has also begun a new initiative on safe use of medical devices in the home. The agency is developing guidance for manufacturers on how to check the physical environment, and it is looking at how caregivers and users interface with new devices. FDA is also conducting post-marketing surveillance.
- While FDA focuses on safety and effectiveness, Medicare focuses on how reasonable and necessary a device is. The agency looks primarily at whether a device provides significant health outcomes. In addition, by law, Medicare can cover only certain types of services and products. The Coverage and Analysis Group relies on evidence of improved health outcomes, but group staff also encourages people to discuss new options with them.

SESSION 3: COPING WITH IMPAIRMENT: EFFORT EXPENDITURE, STABILITY, RANGE OF MOTION, SIMULTANEOUS MEASURES OF INTERACTING FACTORS

Moderator: Evan Hadley, MD, National Institute on Aging

Clinical Needs of Elders Coping with Impairments

Marilyn J. Rantz, PhD, RN, FAAN, University of Missouri

Maintaining and regaining physical function is the primary concern for older adults. Yet measuring physical function is somewhat tricky because of ceiling effects and a lack of standards for measuring ground truth. Researchers at the University of Missouri are working with clinicians to determine gold standards and ways to use technology to build effective measures. Other factors affecting the maintenance of physical function are muscle mass, strength, and motivation. In some cases, convincing older adults that they can maintain muscle mass and strength is difficult, as is motivating them to maintain or improve their physical function. Recent work by Dr. Rantz and colleagues has explored the use of video feedback, but as discussed in previous presentations, many individuals are wary of video. In a theoretical model used at Tiger Place and Aging in Place, Dr. Rantz and colleagues are working to alter the stair-step progression moving through functional transitions associated with health events. They aim to lengthen plateaus by detecting illnesses faster and by assessing patterns of gait and activity.

Managing multiple chronic illnesses is another concern for older adults. The majority of older adults have one or more chronic illnesses, and more than 40 percent need assistance with one or more ADLs. More than 20 percent live in congregate senior housing, about 1.6 million live in nursing home, and 1 million live in assisted living settings. However, most care for older adults is provided by informal caregivers. The need will grow as the population ages; by 2030, one in five adults will be 65 years or older. Technologies will be needed to aid older adults in all these settings, and to help informal caregivers provide care.

Technologies will also be needed to assist in managing mental health, cognition, and social engagement. Data from the motion density maps described by Dr. Marjorie Skubic (see Continuous Monitoring in the Home) have been linked with clinical data retrospectively to distinguish patients who were depressed or had cognitive impairment. These maps are now being used prospectively in the clinic.

Issues seen with older adults are similar to those seen in children. Both groups want to be independent, make decisions, and enjoy their right to self-determination, and maximizing health and function is a primary concern for both groups. Technologies will have to address their needs, and although these needs will outweigh privacy concerns, older adults will still want to control their privacy.

Discussion Point

Studies by researchers in Tiger Place and Aging in Place have yielded evidence that these technologies assist in shortening periods of disability.

Person-Environment Interactions in the Home: Falls Risks and Measurement Opportunities

Jon Pynoos, PhD, University of Southern California

More than a third of adults aged 65 years and older fall each year, and 78 percent of those falls occur in or near the home. Among individuals aged 75 years and older, those who fall are four times more likely to be moved to a nursing home. In most cases, the individual's home is a contributing factor to falls and a major obstacle to independent living. Most housing is not designed for older persons or persons with disabilities. Homes tend to be inaccessible, limit independent function, and present impediments to caregiving. They do not have supportive features; thus older individuals resort to risky behaviors to get around. Although individuals with osteoarthritis of the knee or back have limited flexibility, many important elements in kitchens are near the floor. Likewise, people with limited range of motion might have problems reaching cabinets. Design elements such as handrails that begin before and after the last step on outside steps, stair railings and better lighting on inside steps, walk-in showers with grab-bars and hand-held nozzles, and motion detectors that turn lights on and off, could reduce the risk for falls.

Personal motion technologies, particularly sensors and video, could provide a better understanding of a person's home environment and how it might contribute, for example, to falls. These technologies could be used to see how people carry out tasks within their homes, when falls occur and what a person is doing when he or she falls, what the mechanics of falls are, and whether individuals use recommended supports. Such data could be transmitted to health care service providers and allow them to provide enhanced or targeted services. It should be kept in mind, however, that people want choices, and they want their homes to remain residential in appearance; they do not want their homes to look like nursing facilities.

Discussion Points

- Although video would be advantageous in assessing the home environment and how it contributes to falls, there is still the problem that video is less acceptable than sensors. Ways

must be found to change perceptions of video and to demonstrate their added value in maintaining independence.
- Secondary injuries experienced by caregivers should be studied further.
- The tradeoff between adaptations for safety and opportunities for exercise is a concern. However, exercises that simulate ADLs in a safer manner might be preferable.

From Clinical Requirements to Technical Specifications

Paolo Bonato, PhD, Spaulding Rehabilitation Hospital and Harvard University

To make the transition from clinical requirements to technical specifications, one must answer the following questions:

- How critical is the information to be gathered and relayed by the wearable system?
- How long will individuals wear the system and during performance of what types of motor activities?
- How quickly will it be necessary to relay the information gathered by the wearable system to a remote system, and how quick a response to events is needed?
- How critical will be the integration of wearable sensor data with data collected using sensors and devices in the environment?

Dr. Bonato and colleagues have developed a platform to begin to address impairment and limitation associated with Parkinsonian symptoms and motor complications. The platform also aims to monitor symptom severity and required medication dosage, which fluctuates often during the day. Such a platform will need to gather subjective information and track symptom severity over several time scales. Thus the system will need nodes equipped with inertial sensors, data extraction from the nodes at little inconvenience to the patient, algorithms to translate accelerometer features, annotation tools, and a Web-based application. The platform developed by Dr. Bonato and colleagues is a Sensing Health with Intelligence, Modularity, Mobility, and Experimental Reusability (SHIMMER)-based platform of wireless sensors. It is the only device with extensive memory capability on the nodes, and a Web application has been developed to facilitate symptoms management.

In a second example, a system has been developed to detect seizure in patients with epilepsy. This system is based on a Nokia tablet and takes advantage of wireless or textile-based wearable technologies. In yet another example, Dr. Bonato and colleagues are working on a multidimensional, flexible monitoring platform that uses body and environmental sensors to capture indications that falls might have occurred. Work is still needed to integrate tools with clinical applications and to understand which information should be gathered most immediately from these platforms.

Discussion Points

- Dr. Bonato and colleagues are exploring the use of robots as a flexible and more unobtrusive option for detecting falls. In addition, a system integrating various types of sensors might be useful, particularly at night when a person might not use wearable sensors.
- The systems discussed by Dr. Bonato actually infer falls but could detect conditions related to a fall. False positives are expected.

Sensors, System Architectures, System Integration, and Implementation

Emil Jovanov, PhD, University of Alabama in Huntsville

Most sensor technologies are off the shelf and readily available, and they have undergone several advances and are getting cheaper. To aid in maintaining independence, systems based on these technologies will need to be unobtrusive and easy to use, and they will need to integrate data seamlessly from several sensors and sources. Compliance will be determined by the size and weight of sensors, which in turn will depend on power consumption, communication protocols, and synchronization with other sensors.

Examples of such a system include:

- iSense, an intelligent sensor platform measuring 1 to 2 inches. This platform employs inertial sensors, each of which generates raw and processed data streams.
- deFOG, which detects freezing of gait among Parkinson's patients, streams rhythmic music to a Bluetooth headset, and turns the music off when freezing ends. deFOG provides not only monitoring capability, but also real-time processing and intervention.
- Toumaz, developed in England. This system is a single-chip solution that monitors heart rate and transmits data wirelessly to a cell phone or other device. This system is not yet ready for general use.
- IN-EAR, which monitors vital signs through a sensor embedded in a hearing aid.

Systems could organize wireless body sensors and integrate the information transmitted from these sensors into personal devices and Web-based servers. Dedicated emergency services could be created based on system architecture, and information could be linked with other Web-based information. For example, a personal motion system could be linked with data from the National Weather Service to adjust a person's exercise according to the local weather forecast. The architecture could have multiple layers of access, from the sensor and personal system to Web-based and medical services. Personal motion systems also could employ hybrid solutions. For example, the Avatar system uses remote technologies and inertial sensors embedded in the clothes to monitor real-time body positions.

Systems architectures, integration, and implementation must address:

- Design space. The needs of the application must be matched with the best technologies.
- Power consumption. Communication from devices involves a large waste of energy, and even with the new wave of smartphones, there are no low-power interfaces. Better power sources and battery technologies are needed.
- Sensor availability. Sensors must be reliable, configurable, and interoperable.
- Connectivity. Systems must provide real-time connectivity and avoid collisions among various devices. Advanced communication interfaces are needed.
- Sensor and system intelligence. Such intelligence could improve the level of service overall.

Session Discussion Points

- These technologies will become more attractive to clinicians if the high-resolution information captured from sensors can be related to clinical measures.

- Technologies also should be robust and simple, with an easy-to-use interface, for medical professionals to adopt them. An emphasis on "fancy or complicated gadgets" could create a false impression of technologies and result in a public backlash.
- A retrospective evaluation of the information captured from these new technologies will increase understanding of causes of and risks for falls. Work is under way to improve risk assessment and fall detection. Both technical and clinical knowledge of risk factors will be needed.

SESSION 4: MANAGING MILD COGNITIVE IMPAIRMENT AND RETAINING SAFE AND INDEPENDENT LIVING

Moderator: Laurie Ryan, PhD, National Institute on Aging

Mild Cognitive Impairment (MCI) Clinical Needs

Maureen Schmitter-Edgecombe, PhD, Washington State University

MCI, often seen as the transitional state between normal aging and dementia, is a heterogeneous group of etiologies and clinical presentations. About 10 percent to 20 percent of individuals aged 65 years and older have MCI, and of those, 15 percent will progress to dementia each year. Some develop AD every 70 seconds, and if treatments or preventive measures are not found, the frequency will increase to every 30 seconds by the year 2050. Compared with others caring for older adults, individuals caring for patients with dementia provide more hours of caregiving and experience higher emotional stress and more negative impacts on employment and financial security. In addition, patients with dementia undergo more hospital stays and more home health visits, are more likely to be placed in assisted-living or skilled nursing facilities, and thus account for health care costs that are three times greater than those for other conditions. Thus the use of technologies to prevent or slow progression of MCI might be beneficial.

As is the case for other older persons, persons with MCI would welcome technologies that enable them to extend the period of functional independence and allow them to age at home. In addition, MCI patients showing more functional difficulties are more likely to progress more quickly to dementia. Thus, technologies should encourage healthy behaviors and allow caregivers and health care providers to determine when someone is having more difficulty. At present, MCI-associated functional changes are identified through questionnaires and performance tasks, neither of which provides information on specific types of errors committed by the patient. Dr. Schmitter-Edgecombe and colleagues are exploring the use of activity recognition monitoring to identify differences in time to complete tasks and errors committed while completing them. They are also studying the use of cueing technologies as a way to minimize errors.

Technologies must be evaluated in terms of safety, accountability, and efficacy. The best methodology and outcome measures for such an evaluation are not clear. Privacy and confidentiality issues, as well as the question of who can give informed consent for participation in MCI trials, also must be addressed. More work is needed to develop technologies that can monitor disease progression and adapt to progressive deficits.

Function, Independence, and Environment

Joan C. Rogers, PhD, University of Pittsburgh

With the view of disability as an interaction between a person and his or her environment, Dr. Rogers and colleagues have studied older adults with osteoarthritis or dementia, both in a clinical prosthetic environment and in their home environment. They have investigated individuals' ability to perform tasks involved in personal care, mobility, and other independent ADLs (iADLs), as well as how safely these individuals can do those tasks. No differences in independence were observed between clinical and home performance at any time point tested. However, slight decreases in the ability to perform cognitive iADLs were noted at the second time point. No changes in the ability to perform tasks safely were seen over time or between environments. Strikingly, safety improved among dementia patients at the second testing, indicating that safety interventions were still operating 6 months later.

Among patients with MCI, problems with functional mobility were ignorable. However, there were observable differences between patients with MCI and those with dementia in the bed mobility task, stair use, and ability to get in and out of the bathtub. Further study showed similar patterns of differences among groups, with MCI falling between the control, which performed best, and dementia, which performed the worst. Dr. Rogers and colleagues also investigated a hierarchy of cueing and found that individuals with MCI needed more instructions in all ADLs, though they generally did not need more than verbal directive cueing. Cueing was applied to subtasks, rather than to the total task, to identify where problems lay. For example, patients with MCI were more likely to hit their foot while getting into the tub and to show no control as they lowered themselves into the tub.

The ideal technologies should be useful throughout the cognitive continuum, support procedural learning, compensate for normal age-related impairments, and capture the process aspects of activity and non-activity. They should establish and provide alerts for changes in frequency, duration, and patterns of activity, and they should be simple and dependable. In addition, technologies should be tested for and evaluated in the environments in which they will be used.

MCI Trials

Terrance O'Shea, PhD, Intel Corporation

Early studies have shown that older people with MCI can benefit from greater social engagement. Dr. O'Shea and others at Intel have created and are testing a computer-based system to promote contextual awareness and improve social engagement. The system asks seniors and caregivers to log the time, duration, and quality of visits; allows seniors to click or roll pictures of family and friends to identify them; installs chair pads that notify caregivers when the senior sits in a certain chair; uses door mounts to track when people visit and telephone monitors to track incoming calls; and employs a badge to track how much time a visitor and the senior spend together in one room. On the basis of data captured from these sensors, computer screens show the senior as the center of a universe and place others in proximity based on the number of interactions with the senior. The system also includes a screen that shows a picture of who is calling, how that person is related to the senior, and something the two talked about during the last call.

Intel is also collaborating with the Dublin-based Technology Research for Independent Living (TRIL) Centre to investigate ways to improve cognitive awareness by focusing a senior's attentiveness. Seniors use a SHIMMER device with a push button to answer questions on a small screen, and galvanic skin response is used to track their attentiveness while they perform this task. In an ongoing study, seniors are building their awareness, working through training manuals, and practicing self-alerting. Data analysis is under way.

Intel is exploring voice motion and conducting a Dear Diary project, which monitors speech on the phone and compares speech patterns in an attempt to distinguish between cognitive impairment and cognitive improvement. In addition, Intel has also performed gait analysis, using sensors and SHIMMER technology in combination with a full medical evaluation, to get a better understanding of a patient's cognitive stage.

Mixed Sensing for Health Care Applications

Ruzena Bajcsy, PhD, University of California, Berkeley

As discussed throughout the workshop, there are separate sensing and communication technologies on the body, in buildings, and outdoors, but these technologies should be integrated into a system architecture. Dr. Bajcsy and colleagues have built such an architecture based on Intel-based SHIMMER motes as sensors and on commodity components such as cell phones with Bluetooth communication and an Android operating system. It is hoped that scalability and costs will be reasonable, but issues of interfacing among devices and among institutions must be overcome.

CalFIT is one application that can be used with this architecture. This application embeds an accelerometer and the Global Positioning System (GPS) in a cell phone that is programmed to interface with a particular server. The application allows individuals to score their daily and dedicated exercise, upload their scores onto the server, and compare their scores and progress with others at similar exercise levels. Tests of CalFIT in obese children are under way. A second application, TeleImmerse, uses several cameras to reconstruct how people move in real time. TeleImmerse allows communication between locations and provides a virtual environment in which two people appear to be dancing together, even though they physically are dancing by themselves. Magnetic resonance imaging and other three-dimensional procedures could be integrated into this system, providing a way for multiple sites to collaborate medically. Efforts to build a broadband HealthNet, which will connect medical schools and rural hospitals, are under way.

Session Discussion Points

- The cueing mechanisms used by Dr. Schmitter-Edgecombe's group used a different hierarchy than those used by Dr. Rogers' group. Both groups hope to use machine learning to develop cueing mechanisms that pinpoint problems and mimic mechanisms used by a caregiver.
- Securing funding for technology development is particularly challenging. Several iterations are needed to get a technology working, and reviewers often view the amount of preparation as unnecessary. In addition, clinical technology development is often a multidisciplinary project, which traditionally has not succeeded in NIH study sections, and although the

National Science Foundation (NSF) is interested in algorithm development, NSF reviewers are hesitant to recommend support for research involving human subjects. More effort is needed to increase awareness of the importance of technology development, and relevant Federal agencies (Department of Defense, NIH, NSF, National Institute of Standards and Technology [NIST], National Institute of Disability and Rehabilitation Research [NIDRR]) should consider collaborations.

- A myriad of technological solutions are available and could provide a large amount of data, but which data is most important for which clinical application should be identified. The simplest solutions should be found for, and support targeted to, a given application.
- Interoperability, among devices and among institutions, remains a problem. More research is needed to develop standards and universal data formats. Information technology and HIPAA standards are in place, but standard technical taxonomies are needed for clinical health records, and these taxonomies must gain acceptance from clinicians.

SESSION 5: REHABILITATION AND EXERCISE IN THE HOME

Moderator: Ralph Nitkin, PhD, The Eunice Kennedy Shriver National Institute of Child Health and Human Development

Disability, Secondary Conditions, Rehabilitation, and Exercise

Kenneth Ottenbacher, PhD, University of Texas Medical Branch, Galveston

According to data from the U.S. Census Bureau, approximately 19 percent of Americans have a disability involving activity limitation, and the incidence of disability increases with age. Although disability is more prevalent among males at younger ages, it is more prevalent among females at older ages. On the basis of data from the National Health Interview Survey, 18 percent of working-age adults have a disability, and that incidence increases to 54 percent among older adults.

Although disability is often considered a progressive process, it is also a dynamic one, and individuals often move in and out of disability states. For example, data from a survey of older Mexican-American adults showed that the distribution of frailty, defined based on criteria by Fried et al., changed over a 12-year period. Individuals who were categorized as frail at one time point did not remain in that category.

Persons with disabling conditions often experience secondary conditions, defined by *Healthy People 2010* as "medical, social, family, or community problems that a person with a primary disabling condition likely experiences." In the Massachusetts Survey of Secondary Conditions, 656 respondents with disabilities reported an average of 5.3 secondary conditions, and 95 percent of them reported at least one. The most common secondary conditions were paralysis or mobility impairment, followed by mental health issues and chronic pain.

Studies have shown exercise to be effective in combating disability. Personal motion technologies might thus be welcome in sites where rehabilitation and exercise are provided, including inpatient rehabilitation centers, skilled nursing homes, a person's home and community, and community-based rehabilitation models. Despite the myriad benefits of exercise, however, compliance with exercise regimens remains a problem. Thus, in order to be

accepted by individuals who need them the most, technologies should be designed to make exercise better and more effective and to accommodate ethnic and cultural considerations.

Discussion Points

- Although there are other definitions of frailty, Dr. Ottenbacher and colleagues have used Fried's definition, which is based on performance in walking speed, grip strength, unintentional weight loss, physical activity, and exhaustion/fatigue.
- Because of changes in the payment system, the number of people receiving rehabilitation services in inpatient centers has decreased. The effectiveness of other venues in providing rehabilitation is not yet clear. However, patients who have undergone joint replacements tend to do better in the home, where they move around more.
- As an example of ethnic differences in how exercise is viewed, the majority of the Mexican-American sample said they did not exercise, meaning they did not engage in formal exercise programs. However, they were active. How one conceptualizes and engages in exercise differs among populations. Personal motion technologies could monitor and encourage activities that are not directly considered exercise.

Remote Monitoring and the TRIL Centre

Desmond Fitzgerald, MD, University College Dublin

Remote monitoring yields several opportunities, but it also faces several challenges. Monitoring technologies capture unique information that might not be seen in the clinic, but a common platform is needed to integrate this information. Technologies also need to provide useful clinical information that is specific to the patient, and they need to help clinicians determine when to intervene and whether to do so in the home. The clinical impact of technology is difficult to address, and proving that a technology works within the clinical trials infrastructure is somewhat complicated. Yet there is an extraordinary business opportunity: several technologies already have been developed by companies around the world, and these companies could be attracted and engaged by the development of technological standards.

Funded by the Irish government, the TRIL Centre is a joint program between industry and academia that conducts research of older people in their homes and examines how technology can enable health and social care. Although Intel was initially the sole industrial partner, GE Healthcare and smaller local companies have since gotten involved. The TRIL Center relies on a design-ethnography process that facilitates the development and deployment of technology, and TRIL platforms enable translation of hospital- and laboratory-based research into the home and community. The TRIL team is a multidisciplinary one that includes clinicians, engineers, psychologists, and people interested in sports medicine.

Projects at the TRIL Centre include:

- The Falls Prevention program, which uses SHIMMER devices to measure gait.
- A program using a remote system to assess cognition among older individuals in their homes.
- Building Bridges, a social networking program that allows individuals to communicate with their families and with others on the network and engages them in training exercises.

Because many older people prefer a phone over the computer, Building Bridges includes a custom-made device with a telephone.

- BioMOBIUS™, a platform developed at the University of Genoa, that enables rapid user-based integration of different software and hardware platforms.
- A separate project based at UCD's Geary Institute is using remote technology to integrate online day reconstruction, psychometric measures, ecological assessments, and biological markers in real-world situations. For example, this platform has integrated heart-rate and GPS monitoring to assess the reaction in traffic.
- Remotely collected data provides unique information. There is however a need to focus on relevant and specific clinical data in developing remote technologies. For example, in blood pressure measurement, it is nighttime blood pressure that has the highest risk for cardiovascular disease.
- Clarity, a large-scale program in which computer scientists and engineers are developing technology that senses and integrates data on individuals' preferences, intentions, and physical status.

Scalability, fidelity, ability to work in large-scale deployments, and real-time discovery of relevant and reputable information are key challenges in developing the next generation of sensing technologies. However, these technologies do not have to be complicated. For example, a home appliance recognition system could use a monitor attached to the main fuse box; no motion detection sensors are needed. Remote monitoring technologies have a lot of potential for assisted-living and home health care. They also can be used in biosocial surveys and in new types of clinical trials.

Discussion Points

- On the role of each partner, industrial partners bring a focus and objectives to the work of academics. In return, they receive access to patients in their homes and to knowledge gained by academics.
- The development of technology can be facilitated by setting standards. The Danish health system has developed an initiative that develops standards and encourages vendors to develop and integrate technology to meet those standards. The wide array of health care providers in the United States and possible difficulties in getting them to work together is a concern.
- The European Union Framework program encourages problem solving and integration, rather than the development of many different systems. This framework is being extended beyond the EU, to include extended to the United States and the BRIC countries (Brazil, Russia, India, and China). Dr. Fitzgerald offered to discuss the EU framework programs with interested workshop participants.

Clinical Needs

Thomas Gill, MD, Yale University

Because of decades-long trends toward shorter hospital stays, patients often are discharged to subacute facilities within 20 days, despite underlying conditions. Thus, when they return home, patients often are recovering from underlying medical conditions and from declines or

disabilities that led to the hospitalization. Rehabilitation in older persons therefore occurs primarily in the home, most commonly through a visiting nurse service supported by Medicare.

Transitions in care from the hospital to the subaute and home environments represent high-risk periods, with high rates of complications from the initial illness or from a new illness. Other complicating factors include new medications and more complex regimens, as well as new recommendations for self-care, many of which are conflicting. Many older patients experience altered mental status, worsening depressive symptoms, and visual and hearing impairments, all of which make the implementation of recommendations more difficult. Adherence becomes even more difficult if the person lives alone.

Technologies are thus needed to monitor medical factors, safety, personal care needs, and rehabilitation needs, both during transitions in care and in the patient's home. In addition, aging husbands and wives often have significant care needs, and their family members live far away, so technologies are needed to provide peace of mind. Yet, as discussed throughout the workshop, privacy can be a concern, particularly with respect to personal care. Reimbursement issues also must be addressed. Traditional Medicare will be slow to embrace new technologies; thus capitated systems such as Kaiser and Group Health might offer the best opportunities for translating technologies into the community. Demonstrating cost-effectiveness will be critical. Thus focusing on transitions in care, which could reduce the cost of hospital readmissions, could also provide opportunities for translation.

Discussion Points

- The current health care system does not allow enough communication for clinicians to assess patients' needs and mindset. Technologies that would facilitate communication between the home and the clinic or office would provide a better understanding of the patient's needs.
- Several studies have demonstrated that nurse care coordination is a cost-effective strategy. Changes should be made in the regulations to allow for reimbursement for nurse care coordination. A demonstration project conducted by the Centers for Medicare and Medicaid Services (CMS) has shown cost-savings in a partial nurse care coordination model.
- Technologies in home care, in which a physician can view medical records and communicate with clinicians through an e-portal, should be expanded into all home-care agencies.
- Technology and monitoring would have to be adjusted to each individual's needs during transitions in care. Algorithms could be developed to integrate preferences and needs.
- Patients are often asked to try rehabilitation techniques in various settings before the physician or clinician prescribes them. Yet, although patients might like the technique, they might not find it useful for the long term.
- Webcams have been used in remote wound care. Similar systems could be used for other modalities.

Technologies and Barriers

Jim Osborn, MS, Carnegie Mellon University

Several classes of technologies could be employed in the home:

- Exerciser technologies, such as suits with embedded accelerometers and sensors or cameras that monitor an Xbox 360 player's movements, measure a person's full dynamic motions. However, it is not clear whether individuals would use these technologies in a realistic or faithful way, and some older people might not use them at all.
- Therapeutic robots have been developed and have shown a benefit in the laboratory. However, these robots are complicated and expensive and thus not yet ready for home use. In addition, it is not clear whether exercising in virtual reality or becoming more active in ADLs and iADLs is preferable.
- Wearable robots have also been developed, but these are not ready for the home because of issues with cost, complexity, conspicuousness, battery life, and user interaction.
- Coaches such as Adidas' miCoach help individuals track exercise and share their logs with others. Other coaches, such as Carnegie Mellon's Improving Physical Activity through Context, help individuals keep track of their daily activities, highlight moments when they were physically active, and point out opportunities they might have missed. However, actually motivating behavior, providing appropriate real-time feedback, and providing useful and useable interfaces for clinicians and patients remain challenging.

These technologies are still immature, and evidence of efficacy and cost-effectiveness is still scarce. Thus is not clear how they will be accepted by patients and clinicians. For example, patients might wonder whether they can still cheat, or they might view a trip to the therapist's office as a chance to get out of the house. Clinicians, on the other hand, might suffer from data overload or be unwilling to accept solutions based on games. Privacy concerns have been discussed throughout the workshop. And importantly, it is not yet clear whether a business can be built around these technologies or whether markets can be expanded, thus lowering costs. Moreover, translation of these technologies is hampered by reimbursement issues. For example, Medicare might not reimburse for telehealth, and it does not pay for devices that might have secondary purposes. Finally, issues of liability must be addressed. Addressing all these barriers will require multidisciplinary approaches that involve clinical, social, and technological components and build on what has already been done elsewhere. A toolbox approach, which would provide a common platform from which users could draw tools, might be useful.

Discussion Points

- Whether physical activity is carried out in a virtual setting or natural context might not matter, so long as the technology makes physical activity fun and thus encourages it.
- Approximately 70 percent of people are no longer participating in exercise programs after 1 year, but reasons for failure are not known. These technologies might provide more information about what happens after people achieve the goals of a diet or exercise program.
- Grandchildren might play an important role in helping older people accept new technologies, especially those built on gaming.

Session Discussion Points

- Emphasizing physical activity, rather than formal exercise, might be preferable. In many cases, someone says she does not exercise, but she is getting the recommended amount of physical activity. *Healthy People 2020* has changed its focus area from physical activity and exercise to just physical activity.

- NIDRR is a potential funder, as it spends a large proportion of its budget on research and development.
- The Rehabilitation Engineering Research Center at the University of Southern California is building on virtual reality gaming to address compliance and motivation challenges.
- The FDA does not want to stifle innovation. Instead, it is working within its regulatory purview to guide manufacturers for technologies that will be used in the home. Technology developers are encouraged to work with FDA to determine whether their technologies are in fact medical devices.
- The American Association of Medical Instrumentation and the International Electrotechnical Commission have developed standards for home medical equipment.
- The United States Access Board emphasizes that accessibility should be included as a criterion for technologies and considered a core value, similar to safety and efficacy. Barriers that would make products difficult to use should be reduced or eliminated. The Federal Interagency on Disability Research has guidelines on this issue.

SESSION 6: HELPING THE HELPER—ADDRESSING THE NEEDS OF THE CAREGIVER

Moderator: Jonathan King, PhD, National Institute on Aging

Impact of Caregiving and Caregiver Support

Tonya Miller, PT, DPT, COS-C, Celtic Healthcare

An estimated 37 million people will be providing informal care in the home by the year 2030. Mostly older and middle to older age, informal caregivers are still working outside the home, but they provide 8 to 40 hours of care per week, for an approximate economic value of $196 billion per year. The proportion of people providing informal care is evenly distributed among ethnic groups, at about 20 percent. However, the proportion is higher among African and Hispanic Americans as the patient ages, and the relationship of the caregiver to the patient differs with race and ethnicity. Differences also exist among groups in terms of who is providing care, the caregiver's educational level, the use of formal resources, and the financial resources available to them.

A third of all caregivers report that they are in poor health, and they are less likely to participate in their own preventive care because of all the responsibilities they face. They are at increased risk for coronary heart disease, and they undergo a large number of physical demands as they assist with ADLs. Women caring for spouses are at increased risk for depression and anxiety, even more so than those caring for a parent or child. All of this excess strain increases the risk for future illnesses, and caregivers' mortality risk increases by 63 percent.

Caregivers also face extensive financial burden in the form of lost wages, lost retirement benefits, and increased costs associated with their own care. In addition, to accommodate the additional demands of caregiving, they can be forced to work multiple part-time jobs that do not offer health or retirement benefits. These burdens are estimated to exceed $600,000.

The current home-health benefit does not help informal caregivers. It pays on an episodic model, in which a lump sum is distributed among agencies, and more money is thus given to skilled care

than to caregiver assistance. Fee-for-service models pay only for three to five weekly home health aides. The Caregiver Strain Index is a useful screening tool that home care agencies can use not only to assess strain, but also to guide decisions on where resources and interventions are needed. Technological caregiver support faces several environmental, financial, language, and educational barriers. In addition, caregivers are faced with so many decisions that learning a new technology might be overwhelming, and many of them fear or mistrust technology.

Discussion Points

- CMS does provide some Medicare benefits for telehealth. More information can be found at: www.cms.gov/MLNProducts/downloads/TelehealthSrvcsfctsht.pdf.
- NIA has sponsored a successful caregiver intervention, Resources for Enhancing Alzheimer's Caregiver Health, which is low-tech and cost-effective enough for implementation outside a clinical trial. It has been adopted by the U.S. Department of Veterans Affairs (VA) and other agencies.

Caregiver Health

Kathy Brill, Med, MPS, National Advisory Board on Improving Health Care Services for Seniors and People with Disabilities

Technological advances that assist consumers and caregivers encompass the six principles cited by the National Advisory Board on Improving Health Care Services for Seniors and Disabilities as necessary for modernizing health care infrastructure. As illustrated by Ms. Brill's experiences caring for a daughter with a disability, technology can have a remarkable impact on a family. A large number of technologies are available, and many of these have helped Ms. Brill's family as caregivers and enhanced her daughter's independence. As noted during Ms. Miller's presentation, caregivers usually suffer worsening health as manifest in stress, panic attacks, pain and headaches, depression, and weight change. Yet many families are unaware of the technologies available to help them. Thus more education and outreach is needed.

Of the individuals needing long-term care in the United States, 10.9 million reside in the community, compared with 1.8 million in skilled nursing homes. Many seniors are still caring for adult children with disabilities. Only 13 percent of community residents receive paid help. Most spending for long-term care goes to the minority of residents living in nursing homes, where per-person expenditures can be five times as high as those in the community. Medicaid dollars can support nearly three seniors or people with disabilities in home- and community-based settings for every one person in the nursing home. Yet many states have extensive waiting lists for access to Medicaid Aged/Disabled Waiver Services.

Technologies should address the unique needs of children with disabilities and older adults. Technology developers should listen and observe, consider individual cases, encourage both patients and caregivers, and consider mentoring to facilitate adoption of a technology by the community. Technology supports independence, which in turn supports caregiver health and further independence.

Discussion Points

- As a caregiver, Ms. Brill would rather face the risk of false positives than worry that no one will know when her daughter needs help. She would also like a backup plan.
- Many families do not have the opportunities or resources to move into new, barrier-free houses. Funding and support mechanisms should be found for these families.

State of Technologies Aimed at Helping the Helper

Majd Alwan, PhD, American Association of Homes and Services for the Aging

The Center for Aging Services Technologies (CAST), a consortium within the American Association for Homes and Services for the Aging, operates under the vision that technology can shift care from high-cost settings back to the lower-cost home setting through layers of services. The first line of defense consists of the seniors, who can be empowered to help themselves. However, there are many helpers, all with different needs. Emergency responders need to be able to respond to differences in ADLs and dispatch services; informal caregivers need access to information, sensory data, and feedback; health care professionals need complete assessments of health and wellness, potential risks and preventive interventions, and the ability to evaluate and adjust treatment plans. On the basis of several pilot projects conducted by CAST, communication improves significantly when all stakeholders have access to the same objective information.

Several classes of technologies are available to help the helper:

- Safety technologies. Wearable devices do not work that well, although more systems are designed for auto-alerts and rely on accelerometer and some integrate other modalities. False positives continue to be an issue, but these could be easily addressed by machine learning or by prompting the user to cancel the alert. Environmental and passive devices can alert others when motion is not taking place or when a fall might have occurred.
- Physical and mental health/wellbeing devices. These include wearable devices such as cardio or blood pressure monitors; environmental sensors that assess activity, gait, or sleep; and telemedicine stations that connects with devices and monitor biometrics. Cognitive assessment, orthotic, and reminder systems are still under study.
- Social connectedness devices. These devices, such as phones, two-way video conferencing, and entertainment/"therapeutainment," directly affect quality of life. Gaming and therapeutainment technologies are particularly exciting. Although their effectiveness is not yet proven, users are enthusiastic about them.

Reimbursement and integration issues continue to present a barrier for uptake of these technologies. EMRs and point-of-care systems will prove to be the cornerstone for success. VA, Kaiser, Medicare's Program of All-Inclusive Care for the Elderly, and pay-for-performance models have shown promise, but these are hard to generalize. Medicaid-related programs are evolving more quickly because of extreme pressures, and the CLASS Act and health care reform will hopefully encourage technology adoption. All these technologies are scalable with the right strategic alignments and with payment models that reward all parties, particularly health care professionals. Standardized functional assessments are needed, as are care-coordination, self-help, and caregiver tools that are integrated with EMRs.

Addressing the Information Needs of the Caregiver

Bo Xie, PhD, University of Maryland

Many health organizations, including NIH, release information on the Internet, but older adults and persons with disabilities likely have low Internet literacy. Efforts are needed to promote not only health literacy, but also e-health literacy, defined as the ability of a person to access, understand, and use reliable health information through electronic sources. Web sites should be designed for usability and meet Section 508 guidelines for disability and NIA/National Library of Medicine guidelines for readability by seniors. Guidelines are also needed for social media and social networking sites such as Facebook.

In a study conducted comparing the usability of web-based, multimedia health tutorials, Dr. Xie and colleagues have found that interactive tools such as exercises or quizzes can be helpful when matched with the right audience, that information should be segmented before the big picture is presented, and that cartoons are more enjoyable than real representations. Another study working with older adults who use social media has addressed privacy concerns, encouraged these adults to read existing content before contributing their own, and emphasized the relevance of technologies to individuals' lives.

Dr. Xie and colleagues have also addressed ways to overcome cost barriers, such as using technologies that are only as complicated and as powerful as necessary and tapping into existing infrastructure such as public libraries. In addition, technology should help users shift from needs to wants, or health information a user would like to have to make important decisions related to diagnoses or standard treatments. Instruments are therefore needed to measure individuals' preferences for health information.

Session Discussion Points

- Some adoption of commercial systems that connect caregivers and patients has been seen, particularly under Medicaid waiver programs. Technology producers are working with aging services and with home and community providers to deploy devices and provide hands-on assistance.
- Although a large body of literature suggests the importance of social connectedness and integration in health, the mechanism is not yet clear. Thus, which social networking modality might be successful is not known. More collaboration is needed between clinicians and social scientists.
- Consumer Reports and Amazon Reviews might provide models for evaluating these technologies in the future. However, other types of evaluation models will be needed at the systems level.
- Technology developers also should look to multipurpose devices, such as the iPhone, where different subsets of applications are used by different people. The kinds of information that are wanted and needed will differ across individuals, but outreach efforts should at least educate all users on available features.
- The CLASS Act will make long-term care insurance available to more people, but the ramifications of this Act are not yet understood. Many details are still under discussion.

Suggested Resources

- Technology for Long-term Care: www.techforltc.org
- Abledata, an NIDRR-maintained comprehensive database of assistive technologies: www.abledata.com
- A clearinghouse on products and technologies open to the public, maintained by the American Association of Homes and Services for the Aging.

WRAP-UP DISCUSSION

Although the technologies discussed during this workshop hold a lot of promise for keeping people in their homes longer, adoption of these technologies by the community is still a challenge. Technologies will have to capture the public's imagination, similar to the space race in the 1950s and 60s. More evidence of their effectiveness, and particularly cost-effectiveness, will be needed. Comparative effectiveness studies are also needed, and because the U.S. health care system is heterogeneous, these studies will have to account for the care model used. Although studies of efficacy and cost-effectiveness will likely be large, long, and costly, the evidence they yield can encourage not only CMS but also a variety of other payers to support the use of personal motion technologies in the home.

The field of technology development is also hampered by the current focus on single components, or "single pieces of the puzzle," when a viable, integrated system is needed. Such a system will require the development of standards and a common platform, and once these are developed, the market will likely determine which devices are most useful.

Effectiveness studies and systems integration should build not only on known devices and technologies, but also on existing infrastructure, including congregate housing and Federally funded senior centers where seniors already receive assistance. Staff could be involved in these studies, for example in recruitment of study participants, and they could extend what they learn from these studies further into the community. However, limited health care dollars and competition for them could be one barrier to leveraging existing resources. Because these technologies are intended for home health care, and because studies might yield evidence that they could aid in preventing hospitalizations, staff at skilled nursing facilities and assisted living centers might feel threatened and be less willing to participate in such studies.

Although the development of personal motion technologies is already collaborative and multidisciplinary, more collaboration is needed. At present, for example, clinicians and technology developers publish in several different areas, and knowledge is therefore fragmented. NIH-supported researchers are required to share their publications on PubMed Central, and CAST has a clearinghouse on products and product development, www.agingtech.org, but more synthesis from across disciplines is needed. Training efforts are also needed to develop the next generation of multidisciplinary researchers, and NIH has funding mechanisms to support such training.

The videocast of this workshop is available at www.videocast.nih.gov. The FDA also has held a workshop on medical device use in the home; the summary of that workshop can be found at www.fda.gov/medicaldevices/newsevents/workshopsconferences/ucm205804.htm. Discussions

and recommendations from a 2008 workshop on rehabilitation technologies held by CMS might also be useful. The public is also encouraged to visit www.cms.gov/MLNProducts/downloads/TelehealthSrvcsfctsht.pdf to learn about services and technologies already supported by CMS.

The workshop closed with a reminder from the American Association of People with Disabilities that the design of these technologies should ensure accessibility and usability and that these should be core values at the same level as efficacy and safety. There should be no technological discrimination; otherwise these technologies will ignore the needs of 20 percent of the U.S. population and hinder technology adoption overall. The Association supports the current accessibility standards and calls for a Federal interagency meeting if new standards are needed.

APPENDIX 1

BIOGRAPHICAL SKETCHES OF PRESENTERS

Majd Alwan, PhD is the Director of the Center for Aging Services Technologies (CAST). He is responsible for creating and leading a network of technology companies, providers, and research institutions focused on technology solutions for an aging society. Prior to joining CAST, Dr. Alwan served as an Assistant Professor and the Director of the Robotics and Eldercare Technologies Program at the University of Virginia's Medical Automation Research Center. His research interests include passive functional and health assessment, biomedical instrumentation, as well as eldercare and assistive technologies. He is a Senior Member of the Institute of Electronic and Electrical Engineers (IEEE) and a member of IEEE-USA's Medical Technology Policy Committee. Dr. Alwan received his PhD in intelligent robotics from Imperial College of Science, Technology and Medicine, University of London, an MS in control engineering with distinction from Bradford University, and a BS in electrical engineering from Damascus University.

Ruzena Bajcsy, PhD is a Professor of Electrical Engineering and Computer Sciences at the University of California, Berkeley, and Director Emeritus of the Center for Information Technology Research in the Interest of Science (CITRIS), an initiative bringing together the University of California campuses at Berkeley, Davis, Merced, and Santa Cruz with private industry to develop ways to use information technology to affect people's daily lives. Her current research areas include artificial intelligence; biosystems and computational biology; control, intelligent systems, and robotics; graphics and human-computer interaction; computer vision; and security. Her former positions include directing the Computer and Information Science and Engineering Directorate at the National Science Foundation where she managed a $500 million annual budget, Founding Director of the General Robotics and Active Sensory Perception Laboratory, and Chair of the Computer and Information Science Department at the University of Pennsylvania. Dr. Bajcsy is a Member of the National Academy of Engineering and the Institute of Medicine as well as a Fellow of the Association for Computing Machinery (ACM), the Institute of Electronic and Electrical Engineers, and the American Association for Artificial Intelligence. She is the recipient of numerous honors, including the ACM/Association for the Advancement of Artificial Intelligence Allen Newell Award (2001), the Computing Research Associates Distinguished Service Award (2003), the ACM Distinguished Service Award (2004), the Benjamin Franklin Medal for Computer and Cognitive Sciences (2008), the Anita Borg Technical Leadership Award (2009), and the IEEE Robotics and Automation Pioneer Award (2010). She also was named one of the 50 most important women in science in the November 2002 issue of *Discover* magazine. She has served on numerous advisory boards and committees, including the President's Information Technology Advisory Committee (2003-2005). Dr. Bajcsy received her master's and doctoral degrees in electrical engineering from Slovak Technical University in 1957 and 1967, respectively, and a PhD in computer science from Stanford University in 1972.

Paolo Bonato, PhD serves as Director of the Motion Analysis Laboratory, Spaulding Rehabilitation Hospital, Boston, Massachusetts. He is an Assistant Professor in the Department of Physical Medicine and Rehabilitation, Harvard Medical School, Boston, Massachusetts, and he is a member of the Affiliated Faculty of the Harvard–MIT Division of Health Sciences and Technology, Cambridge, Massachusetts. His current research interests focus on technology in rehabilitation with special emphasis on wearable technology and robotics. Dr. Bonato is an Elected Member of the Institute of Electronic and Electrical Engineers (IEEE) Engineering in Medicine and Biology Society (EMBS) AdCom, and he is President of the International Society of Electrophysiology and Kinesiology. He served as Chair of the IEEE EMBS

Technical Committee on Wearable Biomedical Sensors and Systems in 2008 and has been a member of this committee since its inception in 2006. He received an M.S. in electrical engineering from Politecnico di Torino, Turin, Italy, in 1989 and a PhD from the Università di Roma "La Sapienza" in 1995.

Kathy Brill, MEd, MPS serves on the boards of the National Advisory Board on Improving Health Care Services for Seniors and People with Disabilities, Pennsylvania TASH (President), National Coalition on Self-Determination (Secretary), and Parent to Parent USA, of which she is a co-founder. Ms. Brill is a parent of three daughters. Her youngest, age 20, uses numerous supports and assistive technology. She is a staunch supporter of full home and community inclusion, viewing these issues as civil rights protections. For the past 20 years, she has been involved in local and national family support, advocacy, and systems-change efforts. Prior to this, she had been a professional in the field, which allows her the unique opportunity to view issues from both sides of the fence.

Nancy Cullen serves as the Senior Director of Corporate Initiatives and Business Development for the Alzheimer's Association. The team's objectives are to develop mutually beneficial and holistic relationships with companies and organizations to increase concern about the disease and awareness of the association, assist in business planning, and explore the launch of new products and services. Prior to the above role, Ms. Cullen was the Director of Biotechnology Marketing for Monsanto. She led the industry's North American public awareness campaign for consumer biotech acceptance and led Monsanto's corporate reputation campaign.

Desmond Fitzgerald, MD is Vice President for Research and Professor of Molecular Medicine, University College Dublin (UCD). His research is in vascular disease, including the remote recording of blood pressure. He is a Board Member of Technology Research for Independent Living, a joint program with Trinity College, Dublin, National University of Ireland, Galway, and Intel that is developing technologies for home deployment in the elderly, for example, to prevent falls. His prior appointments include the post of Consultant Lecturer in Medicine and Therapeutics at the Mater Misericordiae University Hospital and UCD. In 1994, he was appointed Professor of Clinical Pharmacology at the Royal College of Surgeons in Ireland (RCSI) and Consultant in Clinical Pharmacology at Beaumont Hospital. He established the Institute of Biopharmaceutical Sciences and Surgen, a pharmacogenetics company jointly owned by RCSI and the French genomics company, Genset. He was Chairman of the Health Research Board of Ireland from 2004 to 2007 and has held committee positions in the Irish Medicines Board. He holds an Adjunct Chair in Medicine and Pharmacology at the University of Pennsylvania and was elected to the Association of American Physicians in 2006. Dr. Fitzgerald obtained his medical degree from UCD and subsequently trained in cardiology and clinical pharmacology at Vanderbilt University, Nashville, Tennessee.

Thomas Gill, MD is Professor of Medicine, Epidemiology, and Investigative Medicine and the Humana Foundation Professor of Geriatric Medicine at Yale University. He received his research training in clinical epidemiology as a Robert Wood Johnson Clinical Scholar at Yale, and he joined the faculty in 1994 after completing an additional year as a geriatrics fellow. Dr. Gill is a leading authority on the epidemiology and prevention of disability among older persons and is the recipient of numerous awards, including the 2001 Outstanding Scientific Achievement for Clinical Investigation Award from the American Geriatrics Society and the Ewald W. Busse Research Award in the Biomedical Sciences. He holds several leadership positions at Yale, including Director of the Center on Disability and Disabling Disorders, Director of a postdoctoral training program funded by the National Institute on Aging in Geriatric Clinical Epidemiology, Co-Director of the Claude D. Pepper Older Americans Independence Center, and Director of the Research Career Development Core. His research accomplishments have been recognized through receipt of a MERIT Award from the National Institutes of Health and election to the American Society of Clinical Investigation and Association of American Physicians.

Gregory Hanson, MD is a board-certified internist and geriatrician practicing primary care at the Mayo Clinic since 1990. He has been the Program Director for the Mayo Clinic Geriatric Medicine Fellowship since 2000, is a Member of the Kogod Center on Aging, and is the Medical Director for a local skilled nursing facility. He is currently training in palliative care under the American Board of Internal Medicine track for established clinicians. He is the co-primary investigator for a home telemonitoring study targeted to high-risk, multimorbid elders using the Intel Health Guide. His academic interests include risk stratification of elders and development of new care models for frail elders.

Emil Jovanov, PhD is an Associate Professor in the Electrical and Computer Engineering Department at the University of Alabama in Huntsville. He is recognized as the originator of the concept of wireless body area networks for health monitoring, and he is one of the leaders in the field of wearable health monitoring. Dr. Jovanov is a Senior Member of the Institute of Electronic and Electrical Engineers (IEEE), and he serves as Associate Editor of the *IEEE Transactions on Information Technology in Biomedicine* and *IEEE Transactions on Biomedical Circuits and Systems* and as a member of the editorial board of *Applied Psychophysiology and Biofeedback*. He has spent more than 25 years in the development and implementation of application specific hardware, software, and systems. He has published more than 30 journal papers, 12 book chapters, and 120 conference papers. Dr. Jovanov received his MSc and PhD from the University of Belgrade.

Jeffrey Kaye, MD is the Director of the Oregon Center for Aging and Technology (ORCATECH) and Director of the Layton Aging and Alzheimer's Disease Center, both based in Portland, Oregon. He is a Professor of Neurology and Biomedical Engineering at Oregon Health and Science University (OHSU). He also directs the Geriatric Neurology Program at the Portland Veteran's Affairs Medical Center. His research has focused over the past two decades on the question of why some individuals remain protected from frailty and dementia at advanced ages while others succumb at much earlier ages. This work has relied on a number of biomarker techniques ranging across several fields of inquiry including neuroimaging, genetics, and continuous activity monitoring. A centerpiece of his studies has been the ongoing Oregon Brain Aging Study, established in 1989. He currently leads a longitudinal study (with funding from the National Institutes of Health) using ubiquitous, unobtrusive technologies for automated assessment of elders in their homes to detect changes signaling imminent decline of function. Dr. Kaye has received the Charles Dolan Hatfield Research Award for his work. He is listed in Best Doctors in America. He serves on many national and international panels and review boards in the field of geriatrics, neurology, and technology, including as a Commissioner for the Center for Aging Services and Technology (CAST), Chair of the Working Group on Technology for the Alzheimer's Association, and member of the Advisory Council of the International Society to Advance Alzheimer Research and Treatment (ISTAART). Dr. Kaye received his medical degree from New York Medical College and trained in neurology at Boston University. He was a medical staff fellow in the Laboratory of Neuroscience at the National Institute on Aging before joining the faculty at OHSU.

Tonya Miller, PT, DPT COS-C is currently the Central Pennsylvania/Maryland Regional Director and the Director of Rehab Education and Program Development for Celtic Health Care. In this role, she is the Administrator for both Hospice and Home Health Care and supervises a multi-state interdisciplinary team. In addition to her administrative role, she coordinates the educational pathways for rehab services internally and provides external educational series related to a variety of topics in home health care, rehabilitation, and management. Ms. Miller has presented nationally on a wide variety of home health care topics, and she has published articles in several industry magazines. She has been an active member of the American Physical Therapy Association (APTA) since 1992 and served as the Home Health Section's Newsletter Editor from 2006 to 2010. Presently, she is the Home Health Section's Vice President and serves as the program Chair. Ms. Miller also plays a very active role as a volunteer community leader. In 1994, she co-founded PA Vent Camp, a week-long camp for children who are ventilator dependent. The camp is free to the children and provides respite care for the children's families.

She is a core team member and the Activities Director for the camp, and she leads many of the organization's fundraising efforts. Ms. Miller received her MPT from the Philadelphia College of Pharmacy and Science in 1992 and her DPT from Temple University in 2007.

Terrance (Terry) J. O'Shea, PhD is currently the Senior Principal Engineer and Director of the Rapid Prototype Team in Intel's Digital Group. His current duties at Intel Corporation include projections of technology trends in ubiquitous computing, research and development of sensors for health care applications, and contextual awareness and design of new radio technology for ubiquitous computing. Dr. O'Shea has worked diligently in previous years on creating the Technology Research for Independent Living Centre (TRIL) in Ireland. TRIL is supported by a joint Intel-Irish Development Authority grant for three years and $36 million; focusing on helping people live independently. TRIL is the largest research center in the world of its kind supporting more than 70 academic and industrial collaborative researchers. Previously, Dr. O'Shea was a Staff Architect in System Manufacturing, designing and developing the interface between the processor and the chipset for the Pentium™ III and 4 systems. His designs for packaging are in the Lakeport Chipset, the Pentium® III Processor (Copper-mine), and the Mobile Pentium® II. In his 13 years at Intel he has been awarded the Intel Achievement Award, two TMG Excellence Awards, six Intel Corporation Divisional Recognition Awards, two achievement awards, more than 190 trade secrets, and he filed more than 80 patents. Dr. O'Shea has held faculty positions at the University of Maryland, College Park, and the State University of New York at Buffalo. He has chaired the National Electronic Manufacturers Institution's roadmap for desktop computer systems for the past five years, and for four years he authored the NEMI Healthcare sector roadmap. During his career he has co-authored 1 textbook and more than 80 other publications in electronic packaging, biomedical engineering, computer science, electrical engineering, and structural mechanics. He received his Ph.D. in 1996 from the University of Arizona and his master's and bachelor's degrees from the University of Tennessee, Knoxville, in 1992 and 1990, respectively.

Jim "Oz" Osborn, MS is Executive Director and a Co-Founder of the Quality of Life Technology Center, a collaboration of Carnegie Mellon and the University of Pittsburgh funded by the National Science Foundation as one of its Engineering Research Centers since 2006. He is also the Coordinator of University Life Science Initiatives for Carnegie Mellon. From 2001 to 2006 he was Executive Director of Carnegie Mellon's Medical Robotics Technology Center, as well as MERITS of Pittsburgh, a program to stimulate collaborations between clinical and technological researchers. Previously, he founded a regional economic development group, the Pittsburgh Robotics Initiative. From 1985 through 1999, he held research and management positions in Carnegie Mellon's Robotics Institute and led several multimillion-dollar robotics research and development projects sponsored by the U.S. Department of Energy, NASA, and industry, including the first robot to explore an active volcano and robots for investigation of the Chernobyl and Three Mile Island nuclear accidents. He has served as a board member of several professional society robotics divisions, chaired two technical conferences, and authored 25 papers and technical reports on robotic systems and applications. He holds a bachelor's degree in electrical and biomedical engineering and a master's degree in civil and biomedical engineering, both from Carnegie Mellon University.

Kenneth J. Ottenbacher, PhD holds the Russell Shearn Moody Distinguished Chair in Neurological Rehabilitation at the University of Texas Medical Branch (UTMB) in Galveston. He serves as Senior Associate Dean for Graduate Education and Research and Director of the Division of Rehabilitation Sciences in the School of Health Professions. He is also Director of the Center for Rehabilitation Sciences and Associate Director for the Sealy Center on Aging at UTMB. Dr. Ottenbacher received his Ph.D. from the University of Missouri-Columbia and is a licensed occupational therapist. His research interests include rehabilitation outcomes with a focus on functional assessment, disability, and frailty in older adults. He has published more than 250 scientific/technical articles in refereed journals, and he is the author, coauthor, or editor of 4 textbooks. Dr. Ottenbacher's research has been supported by continuous

federal funding since 1984. He is a member of several editorial boards and currently serves as the Statistical Consulting Editor for the *American Journal of Physical Medicine and Rehabilitation* and Associate Editor for the *Journal of Rehabilitation Medicine*.

Chris A. Otto, MS is President and CEO of Halo Monitoring, a company he co-founded after examining the state of tools available for his own mother who was providing care for his grandmother. Mr. Otto was a pioneer in wireless sensor networks for ambulatory health monitoring, which was the subject of several articles he published in peer-reviewed journals and conference proceedings, as well as of his master's thesis. His work has been recognized as a leading effort in the field of Wireless Body Area Networks (WBANs) for ambulatory health monitoring. Before founding Halo, Mr. Otto worked as a senior design engineer in the field of data and voice communications. He has two issued patents and nine pending patents in the fields of ambulatory health monitoring, wireless networks, data communications, and motion signal processing, including human fall detection. He holds a BS and MS in computer engineering from the University of Alabama in Huntsville.

Joseph Paradiso, Ph.D. is an Associate Professor of Media Arts and Sciences at the Massachusetts Institute of Technology (MIT) Media Laboratory, where he directs the Responsive Environments group, which explores how sensor networks augment and mediate human experience, interaction, and perception. In addition, he co-directs the Things That Think Consortium, a group of industry sponsors and Media Lab researchers who explore the extreme fringe of embedded computation, communication, and sensing. After two years developing precision drift chambers at the Lab for High Energy Physics at ETH in Zurich, he joined the Draper Laboratory, where his research encompassed spacecraft control systems, image processing algorithms, underwater sonar, and precision alignment sensors for large high-energy physics detectors. He joined the Media Lab in 1994, where his current research interests include embedded sensing systems and sensor networks, wearable and body sensor networks, energy harvesting and power management for embedded sensors, ubiquitous and pervasive computing, localization systems, passive and RFID sensor architectures, human-computer interfaces, and interactive media. His honors include the 2000 Discover Magazine Award for Technological Innovation, and he has authored 200 articles and technical reports on topics ranging from computer music to power scavenging. After receiving a B.S. in electrical engineering and physics summa cum laude from Tufts University, Dr. Paradiso became a K.T. Compton Fellow at the Lab for Nuclear Science at MIT, receiving his PhD in physics there for research conducted at CERN in Geneva.

Misha Pavel, PhD is Professor and Head of Biomedical Engineering with a joint appointment in Medical Informatics and Biomedical Computer Science at Oregon Health & Science University. He is the Director of the Point of Care Laboratory focused on unobtrusive monitoring, neurobehavioral assessment, and computational modeling of behavioral and cognitive functions with applications to care for aging and chronically ill populations. Previously, Dr. Pavel was a Technology Leader at AT&T Laboratories, where he developed networked, wireless, and mobile applications for information access and context-aware interactions. While on the faculty at New York University and Stanford University, Dr. Pavel worked on sensor fusion, modeling of pattern recognition in sensory-motor systems, and human computer communication systems. As a Member of Technical Staff at the Bell Laboratories, he developed new approaches to network analysis and modeling by incorporating characteristics of human behavior. Dr. Pavel received his B.S. in electrical engineering from Polytechnic Institute of Brooklyn, his MS in electrical engineering from Stanford University, and his PhD in experimental/mathematical psychology from New York University.

Jon Pynoos, PhD is the UPS Foundation Professor of Gerontology, Policy and Planning at the Andrus Gerontology Center of the University of Southern California. He is also Co-Director of the Fall Prevention Center on Excellence and Director of the National Resource Center on Supportive Housing and Home Modifications. His career has focused on improving housing, communities, and services so

that older persons can age in place. He has advocated for policy changes that facilitate home modifications in existing housing and the development of new housing based on principles of universal design and elder-friendly communities. He has written/edited more than six books and teaches courses on Social Policy and Aging as well as Housing for an Aging Society. Dr. Pynoos was a delegate to the last three White House Conferences on Aging, and he has served as a Member of the American Bar Association (ABA) Commission on Legal Problems of the Elderly and as Vice President of the Gerontological Society of America. He recently received the Award for Excellence in Research, Policy and Advocacy from the American Society on Aging. He has been the recipient of both Guggenheim and Fulbright Fellowships. Dr. Pynoos was the first Director of Minuteman Home Care Corp., an area agency on aging outside of Boston that provides services to keep older persons out of nursing homes. He holds a BA from Harvard College, an MCP from the Harvard School of Design, and a PhD from Harvard University's Graduate School of Arts and Sciences.

Marilyn Rantz, RN, PhD, FAAN has developed and sustained a research program to improve quality of care of older people. Her pioneering work in nursing home care quality spans nearly 30 years, first in practice then as a leading researcher in the Midwest, and establishes her as a premier international expert in quality measurement in nursing homes. Her collaborative research teams are productive, garnering more than $30 million in research funds to support work measuring effectiveness of nurse care coordination, developing new technologies to help seniors age in place in their own homes, as well as ongoing nursing home research.

Joan C. Rogers, PhD, OTR/L is a Professor of Occupational Therapy and Nursing at the University of Pittsburgh, and she also has an appointment in the McGowan Institute for Regenerative Medicine. Dr. Rogers is Chairperson of the Department of Occupational Therapy, and she coordinates the interdisciplinary doctoral program in rehabilitation science in the department. Dr. Rogers' research agenda focuses on methods of assessing activities of daily living (ADL) or instrumental activities of daily living (IADL), non-pharmacological interventions, and functional outcomes of medical, rehabilitation, and psychiatric interventions in geriatric, rheumatologic, and psychiatric populations. Her research includes examination of low- and high-assistive technologies in adults and older adults with cognitive, physical, and affective impairments, and she maintains an active clinical practice with these clinical populations.

Maureen Schmitter-Edgecombe, PhD is a Professor in the Department of Psychology at Washington State University and a licensed psychologist. Her research focuses on evaluating attention, memory, and executive functioning issues in neurological normal and clinical populations with the goal of designing and assessing rehabilitation techniques and smart environment technologies. Dr. Schmitter-Edgecombe received a BS from Bucknell University in 1988 and an MS and PhD from the University of Memphis in 1991 and 1994, respectively. She completed her clinical internship at the University of Arizona Health Sciences Center and specialized in the area of clinical neuropsychology.

Richard Schulz, PhD is Professor of Psychiatry, Director of the University Center for Social and Urban Research, Director of Gerontology, and Associate Director of the Institute on Aging at the University of Pittsburgh. He has spent most of his career doing research and writing on adult development and aging. His work has focused on social-psychological aspects of aging, including the impact of disabling late life disease on patients and their families. He has been funded by the National Institutes of Health for more than three decades to conduct descriptive longitudinal and intervention research on diverse older populations representing illnesses such as cancer, spinal cord injury, stroke, Alzheimer's disease, heart disease, and arthritis. Dr. Schulz has been a leading contributor to the literature on the health effects of caregiving, Alzheimer's disease caregiving, and intervention studies for caregivers of persons with Alzheimer's disease. This body of work is reflected in more than 250 publications, which have appeared in major medical, psychology, and aging journals. He is also the author of numerous books including the

Handbook of Alzheimer's Caregiver Intervention Research. In the past decade, Dr. Schulz has become interested in supportive interventions, including technology-based approaches designed to enhance patient functioning and the quality of life of both patients and their relatives. He is the recipient of several honors, including the Kleemeier Award for Research on Aging from the Gerontological Society of America and the Developmental Health Award for Research on Health in Later Life from the American Psychological Association. He earned his PhD in social psychology from Duke University.

Marjorie Skubic, PhD is currently a Professor in the Electrical and Computer Engineering Department at the University of Missouri, Columbia, with a joint appointment in Computer Science. Dr. Skubic has more than 100 publications and has received funding by the National Science Foundation, the National Institutes of Health, the U.S. Administration on Aging, the National Geospatial Intelligence Agency, the Naval Research Lab, and the U.S. Army. In addition to her academic experience, she has spent 14 years working in industry on real-time applications such as data acquisition and automation. Her current research interests include sensory perception, computational intelligence, spatial referencing interfaces, human-robot interaction, and sensor networks for eldercare. In 2006, Dr. Skubic established the Center for Eldercare and Rehabilitation Technology at the University of Missouri and serves as the Center Director for this interdisciplinary team. The focus of the center's work includes monitoring systems for tracking the physical and cognitive health of elderly residents in their homes, logging sensor data in an accessible database, extracting activity and gait patterns, identifying changes in patterns, and logging alerts that flag possible adverse health conditions. Dr. Skubic received her PhD in computer science from Texas A&M University in 1997, where she specialized in distributed telerobotics and robot programming by demonstration.

George A. Taler, MD is Director of Long Term Care, Department of Medicine at the Washington Hospital Center, and Professor, Clinical Medicine, Geriatrics, at Georgetown University, School of Medicine. His responsibilities include Co-Director of the Medical House Call Program, Vice President for Medical Affairs of MedStar Home Health-VNA and MedStar Home Infusion Services, and Medical Director of Capital Hill Nursing Center, a 114-bed skilled nursing facility in Washington, D.C. Prior to this, he was an Associate Professor in Family Medicine at the University of Maryland. His community leadership activities include Past-President of the Maryland Gerontological Association, 1991-1992; Founding President of the Maryland Geriatrics Society (state affiliate of the American Geriatrics Society), 1993; President of the American Academy of Home Care Physicians, 1998-2000; and current Chair of the American Academy of Home Care Physicians Public Policy Committee. Dr. Taler was a Member of the Board of the National Pressure Ulcer Advisory Panel from 2002 to 2008. Most recently, his efforts have been focused on the development and implementation of the Independence at Home Program, as part of the national health care reform initiative. Dr. Taler graduated from the University of Maryland, School of Medicine in 1975, completed a residency in Family Medicine in 1978, and a Geriatric Fellowship at the Jewish Institute for Geriatric Care (now the Parker Geriatric Institute) in New Hyde Park, New York.

Bo Xie, PhD is an assistant professor in the College of Information Studies at the University of Maryland, College Park. Her research focuses on the intersection of older age, information and communication technologies, and health. (More information about her research can be found at: http://terpconnect.umd.edu/~boxie/.) Dr. Xie holds a BMedSci from West China University of Medical Sciences, an MS in psychology from Peking University (China), and a PhD in science and technology studies from Rensselaer Polytechnic Institute.

APPENDIX 2

FINAL PARTICIPANT ROSTER

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APPENDIX 3

FINAL WORKSHOP AGENDA

June 22 (Tuesday) — Hyatt Regency Bethesda, Embassy Room

6:00 pm **WELCOME RECEPTION (FOR PRESENTERS)**

June 23 (Wednesday) — Stone House / NIH campus

7:45 am **SECURITY SCREENING AND SHUTTLE PICK UP – BETHESDA HYATT REGENCY LOBBY**

8:30 **CONTINENTAL BREAKFAST**

9:00 **Welcome**

Marie Bernard, National Institute on Aging (NIA)
Belinda Seto, National Institute of Biomedical Imaging and Bioengineering (NIBIB)

9:10 **Workshop Kickoff**

Jeffrey Kaye, Oregon Health and Science University

9:30 **Session 1: Detecting Personal Motions and Behaviors as Early Indicators of Disease or Adverse Event Onset**

Panel Moderator:	***William Heetderks***, NIBIB
Clinical Needs:	***George Taler***, Washington Hospital Center
	Nancy Cullen, Alzheimer's Association
Technology:	***Misha Pavel***, Oregon Health and Science University
	Marjorie Skubic, University of Missouri, Columbia

11:00 **BREAK**

11:15 **Session 2: Ubiquitous and Non-Invasive Monitoring of Daily Activities**

Panel Moderator:	***Zohara Cohen***, NIBIB
Clinical Needs:	***Richard Schulz***, University of Pittsburgh
	Gregory Hanson, Mayo Clinic
Technology:	***Chris Otto***, Halo Monitoring, Inc.
	Joseph Paradiso, Massachusetts Institute of Technology

1:00 pm **LUNCH**

2:00 **Session 3: Coping with Impairment: Effort Expenditure, Stability, Range of Motion, Simultaneous Measures of Interacting Factors**

Panel Moderator: ***Evan Hadley***, NIA
Clinical Needs: ***Marilyn Rantz***, University of Missouri
Jon Pynoos, University of Southern California
Technology: ***Paolo Bonato***, Spaulding Rehabilitation Hospital and Harvard University
Emil Jovanov, University of Alabama, Huntsville

3:30 **BREAK**

3:45 **Session 4: Managing Mild Cognitive Impairment and Retaining Safe and Independent Living**

Panel Moderator: ***Laurie Ryan***, NIA
Clinical Needs: ***Maureen Schmitter-Edgecombe***, Washington State University
Joan Rogers, University of Pittsburgh
Technology: ***Terrance O'Shea***, Intel Corporation
Ruzena Bajcsy, University of California, Berkeley

5:15 **SHUTTLE DEPARTS FROM STONE HOUSE TO HYATT REGENCY BETHESDA**

6:30 **GROUP DINNER (FOR PRESENTERS)**
SHANGRI-LA
7345A Wisconsin Avenue, Bethesda, MD; (301) 656-4444

June 24 (Thursday) — Stone House / NIH campus

7:15 am **SECURITY SCREENING AND SHUTTLE PICK UP – BETHESDA HYATT REGENCY LOBBY**

8:00 **CONTINENTAL BREAKFAST**

8:30 **Session 5: Rehabilitation and Exercise in the Home**

Panel Moderator: ***Ralph Nitkin***, National Center for Medical Rehabilitation Research, The Eunice Kennedy Shriver National Institute of Child Health and Human Development
Clinical Needs: ***Kenneth Ottenbacher***, University of Texas Medical Branch, Galveston
Technology: ***Desmond Fitzgerald***, University College Dublin (Ireland)
Clinical Needs: ***Thomas Gill***, Yale University
Technology: ***Jim Osborn***, Carnegie Mellon University

10:00 **BREAK**

10:15 **Session 6: Helping the Helper—Addressing the Needs of the Caregiver**

Panel Moderator:	***Jonathan King***, NIA
Clinical Needs:	***Tonya Miller***, Celtic Healthcare
	Kathy Brill, National Advisory Board on Improving Health Care Services for Seniors and People with Disabilities
Technology:	***Majd Alwan***, American Association of Homes and Services for the Aging
	Bo Xie, University of Maryland

11:45 **Wrap-up and Discussion Summary**

Winnie Rossi, NIA and ***Mary Rodgers***, NIBIB

12:30 pm **ADJOURN**