SPECIAL COMMUNICATION

Workshop on Personal Motion Technologies for Healthy Independent Living: Executive Summary

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The objective of the June 2010 “Workshop on Personal Motion Technologies for Healthy Independent Living” was to discuss personal motion technologies that might enable older adults and individuals with disability to live independently for longer periods. The 60 participants included clinicians, academic researchers, engineers, patient advocates, caregivers, members of the public, and federal representatives. The workshop was divided into 6 sessions that addressed the following: (1) use of technologies in identifying early indicators of disease or adverse events; (2) monitoring daily activities; (3) coping with impairment; (4) managing mild cognitive impairment; (5) rehabilitation and exercise in the home; and (6) caregiver support. Presentations and discussion focused on clinical needs, the health impact of addressing those needs, state-of-the-art technologies, and challenges to adoption of those technologies. Conclusions included the following: (1) Involvement of end-users in research and development will increase the likelihood that technologies will be adopted. (2) Integration of differing types of technology into a system that includes clinical measures is required for independent living. (3) Seniors are willing to sacrifice some privacy for an effective technology that keeps them in their homes as long as they control who receives their data. (4) Multilevel and multiscale models are needed to understand motion in the context of the environment and to design effective systems.

Key Words: Caregivers; Independent Living; Motion; Rehabilitation; Remote Sensing Technology; Technology.

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AS INDIVIDUALS AGE, their physical and cognitive capacity is often diminished, hindering their ability to live independently and often necessitating moves to assisted living facilities or skilled nursing homes. At present, there are no good methods for monitoring and identifying problems for these individuals other than personal or caregiver reports. The hope is that collaboration between the engineering and clinical worlds could yield new approaches to allow older adults and individuals with disability to live independently for a longer period. There is also a role for behavioral science in identifying how these approaches can be used most effectively and easily in a targeted population, thus increasing their chances of adoption. 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, the 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, National Institutes of Health (NIH) staff, and representatives from the Centers for Medicare and Medicaid Services (CMS), the Food and Drug Administration (FDA), the National Science Foundation (NSF), and the

List of Abbreviations

CMS Centers for Medicare and Medicaid Services
FDA Food and Drug Administration
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
NIH National Institutes of Health
NSF National Science Foundation
VA United States Department of Veterans Affairs
United States Department of Veterans Affairs (VA). The workshop was video cast live to 80 viewers on June 23 and 40 viewers on June 24. (The video cast 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.)

Workshop participants discussed the potential use of technology for the early identification of disease, monitoring daily activities, coping with physical impairment, managing mild cognitive impairment (MCI), promoting rehabilitation and exercise, and providing caregiver support. In each of the 6 workshop sessions, 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 and recommendations.

Several themes emerged from discussions throughout the workshop:

1. Enhancing adoption with an eye toward the end-user
   - Users should be involved in research and development to increase the likelihood that technologies will be adopted.
   - Implementation and adoption of a technology will be easier if clinicians, patients, and families understand the technology’s clinical value.
   - Accessibility and usability by persons with disabilities should be considered as essential as efficacy and safety.

2. Characteristics of independent living technology systems
   - Independent living technology systems may often require a number of technologic approaches.
   - 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.
   - Clinicians should encourage more physical activity, rather than exercise, because many people are active without participating in formal exercise programs.

3. Needed research
   - Developers and clinicians should work together to identify which data are needed and to develop the simplest solutions possible.
   - Funding agencies and the public should understand that technologies will undergo several iterations between laboratory development and implementation in the community.
   - Multilevel and multiscale models that can account for changes in the environment are needed to interpret the raw data, to understand the context of motion and to design effective systems.
   - More work is needed to detect falls and to understand the risk and causes of falls.
   - Knowledge must be derived from the data generated by personal motion technologies.
   - More real-world testing is needed.
   - To maximize its efficacy, movement monitoring and intervention technology must adapt to the individual.

OVERVIEW: PERSONAL MOTION AND ACTIVITY TECHNOLOGIES IN HEALTHY INDEPENDENT LIVING

The U.S. population is aging and will have chronic illnesses that require an increasing level of health care 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 the community. This shift has been codified in recent congressional legislation and in a digital health revolution that includes electronic medical records, teledmedicine, information-based comparative effectiveness studies, patient-centered medical homes, and accountable care organizations. Effective health care intervention requires the ability to identify changes in an individual’s wellness. Traditionally, this has involved inferences based on functional and physical assessments performed at the convenience of the clinician or investigator that depend heavily on recall or brief snapshots and are assumed to represent typical function. In addition, variability between tests and between observers is high. Thus, with traditional methods, relevant information is lacking or inaccurate, and the resulting assessments of change are imprecise. Personal motion and activity technologies could provide constant data that allow clinicians to see variability and trends or trajectories, rather than individual data 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. Data collected through these technologies, combined with symptoms reported by the patient, could increase the likelihood of early detection and intervention.

Future development should involve continuous improvement in framing basic and clinical questions and solutions, improvement of technology, careful consideration of scalability, evaluation of the ecologic validity of simulation scenarios, and rapid expansion of the evidence base. A wide array of existing technologic platforms, including actigraphy devices, cell phone–based prompters or tracking, and activity, physiologic, and localization sensors, are available, and efforts are underway to apply them more widely in the community.

Workshop participants were asked to consider several points:

- The range and resolution of the data collected should be tailored to the particular need.
- Basic development, prototyping, and demonstrations must be balanced with practical near- and long-term clinical needs and outcomes.
- Real-world applications do not usually conform to theory, and thus iterative modeling may be required.
- One technology does not fit all. The right tool must be matched with the appropriate task.
- The efficacy and effectiveness of technologies should not be overstated without sufficient evidence.
- Technology developers should aim to publish in clinical journals to foster awareness and subsequent communication and collaboration between the communities.

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

Advances in research and technology are providing the potential to identify what changes in motion patterns indicate the start of disease and detect injury. In this session, clinical needs related to early disease or adverse event detection were addressed. Technologic advances that might address these needs were then presented. Related issues and challenges are summarized in the following discussion points.
Session Discussion Points

- Clinicians do not always know the value of measurements they collect. Some measures taken at home are more important than those taken in the clinic. Health cost savings of home assessment using technology is one clear value.
- 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. The problem of wandering is somewhat difficult because individuals want to maintain their dignity, and there is often denial on the part of family members that a person will wander. While it is important to minimize the intrusiveness of personal motion technologies, individuals might be willing to trade some privacy for devices that prove effective. Technologies could be applied to individuals in wheelchairs, assuming other factors captured by motion technology could influence the way they maneuver their chairs. However, this has not yet been studied.
- Variability is important, and monitoring should therefore be done on several scales to distinguish important changes from random ones. Any system that measures deterioration in an individual’s pattern of motion must be appropriately calibrated. In some cases, a population average can serve as a baseline, indicating the “healthy” state to which the individual’s motion pattern will have to be compared. But in many cases, the individual’s motion pattern will have to be compared with his/her pattern at an earlier time. The individual’s characteristic motion pattern would be measured at one time, providing a personalized baseline, and future measurements would be compared with that baseline. In some situations the ideal baseline will be one that is adapted over time and, so, for example, may represent a rolling average (or some other statistical representation) of the pattern over the course of the previous month. Finally, the system will ideally also account for changes in the environment that may affect behavior and health.

SESSION 2: UBQUITOUS AND NONINVASIVE MONITORING OF DAILY ACTIVITIES

Monitoring activities (eg, taking medication) inside and outside the home can increase the independence of individuals with disability as well as the elderly. In this session, clinical needs related to monitoring of daily activities were discussed. Technologic advances that might address these needs were then presented. Related issues and challenges are summarized in the following discussion points.

Session Discussion Points

- More real-world testing of monitoring technologies is needed. Technologies are likely to undergo several adaptations as they make the transition from the laboratory to the community. For example, it is not clear what will happen when the feedback from these technologies begins to affect medical treatment and access to care. Concerns about this issue are already apparent in patients’ unwillingness to have their data shared with insurance companies.
- Furthermore, people want to preserve their personal dignity and privacy, making them particularly concerned about data collected in the bathroom and bedroom. However, these places present the greatest risk for falls, and thus there is a need to balance these concerns with the benefits that can be realized. Technology can provide part of the solution, but the rest must come from discussions and negotiations between patients, their families, and providers.
- The existence of appropriate infrastructure is critical to marketplace adoption and deployment of these technologies. Trust between patients and health care providers is also essential.
- The adoption of personal motion technologies also depends on government regulatory policies for these technologies and the reimbursement policies of private and public insurers. For example, the FDA regulates anything that is classified as a medical device and has 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 is looking at how caregivers and users interface with new devices. Finally, the FDA is also conducting postmarketing surveillance. Clinicians are likely to adopt targeted technologies that are proven to be effective and cost saving.
- While the FDA approves devices based on safety and effectiveness, the CMS determines reimbursement based on how reasonable and necessary a device is. The agency looks primarily at whether a device provides significant health outcomes. In addition, by law, CMS can cover only certain types of services and products. The Coverage and Analysis Group relies on evidence of improved health outcomes and also encourages people to discuss new options with them.

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

Coping with frailty and impairment is necessary for safe and healthy independent living. A number of physiologic measures may be used to assist individuals in maintaining their independence. In this session, clinical needs related to impairment were discussed. Technologic advances that might address these needs were then presented. Related issues and challenges are summarized in the following discussion points.

Session Discussion Points

- Two foci of this session were home-use technologies that improve rehabilitative exercise regimens and technologies to detect falls quickly.
- Studies have yielded evidence that personal motion technologies assist in shortening periods of disability by speeding up recovery. Although video monitoring could have advantages over other sensor systems in assessing the home environment and how it contributes to falls, captured video information is usually less palatable to patients than other motion sensors. Approaches must be pursued to change perceptions of video and to demonstrate their added value in maintaining independence.
- The tradeoff between adaptations for safety and opportunities for exercise is a concern because making robots completely safe often means compromising how much they actually mimic real-life activities. However, exercises that simulate activities of daily living in a safer manner might be preferable to exercise that is not related to functional activities.
- A system integrating various types of sensors that could detect conditions predictive of a fall and relate to clinical measures would be useful for fall prevention. A retrospective evaluation of the information captured from these new technologies will increase understanding of causes of and risks for falls. Work is underway to improve risk assessment and fall detection. Both technical and clinical knowledge of risk factors will be needed.
• Generally, to increase the likelihood of adoption by individuals, their caregivers, and medical professionals, technologies should be robust, simple, and easy to use. Gadgets that are too “fancy” or complicated would create unrealistic expectations that could result in public backlash.

SESSION 4: MANAGING MCI AND RETAINING SAFE AND INDEPENDENT LIVING

A number of chronic conditions include MCI, and changes in cognitive function are expected with aging. In this session, clinical needs related to MCI were discussed. Technologic advances that might address these needs were then presented. Related issues and challenges are summarized in the following discussion points.

Session Discussion Points

• MCI, often seen as the transitional state between normal aging and dementia, is a heterogeneous group of etiologies and clinical presentations. About 10% to 20% of individuals 65 years and older have MCI, and of those, 15% will progress to dementia each year. 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 3 times greater than those for other conditions. Thus the use of technologies to prevent or slow progression of MCI might be beneficial. More work is needed to develop technologies that can monitor disease progression throughout the cognitive continuum, adapt to progressive deficits, support procedural learning, compensate for normal age-related impairments, and capture the process aspects of activity and nonactivity.

• Securing funding for this type of technology development is particularly challenging. Several iterations are needed to get a technology working, and clinical technology development is often a multidisciplinary project, which traditionally has not succeeded in NIH study sections. While the NSF is interested in algorithm development, its reviewers are hesitant to recommend support for research involving human subjects. There is a need for increased awareness of the importance of technology development and collaborative funding mechanisms for the relevant federal agencies (Department of Defense, NIH, NSF, National Institute of Standards and Technology, National Institute of Disability and Rehabilitation Research [NIDRR]).

• A myriad of technologic solutions are available, but the best match between data and clinical application has yet to be determined. 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 Health Insurance Portability and Accountability Act 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

Frailty is a function of performance in walking speed, grip strength, weight loss, physical activity, and exhaustion/fatigue. The ability to provide rehabilitation and exercise in the home is increasing with the development of a variety of technology approaches. Healthy independent living would be available to more individuals if this area could be advanced. In this session, clinical needs related to rehabilitation and home exercise were discussed. Technologic advances that might address these needs were then presented. Related issues and challenges are summarized in the following discussion points.

Session Discussion Points

• In many cultures, a physically active lifestyle may not necessarily incorporate recognized exercise. In recognition of this conceptual issue, Healthy People 2020 has changed its focus area from “physical activity and exercise” to just “physical activity” (http://healthypeople.gov/2020/topicsobjectives2020/overview.aspx?topicid=33).

• Personal motion technologies could monitor and encourage activities that are not directly considered exercise, thereby emphasizing physical activity rather than formal exercise. 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. 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 their grandparents accept new technologies, especially those built on gaming. Industrial-academic partnerships are critical to development of these technologies.

• There are differences in national approaches to home and mobile use technologies for independent living. In the United States, the decentralization of health care delivery can often be an impediment.

• 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. Technologies in home care, in which a physician can view medical records and communicate electronically with home care providers on site, would likely improve outcomes for home-care delivery systems. 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 clinician prescribes them. Yet, although patients might like the technique, they might not find it useful, effective, or easy to follow for the long-term.

• Webcams have been used in remote wound care. Similar systems could be used for diagnosis or treatment of other conditions.

• The United States Access Board has guidelines on accessibility that should be included as a criterion for development of these technologies (appendix 1).

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

The role of caregivers is often overlooked and yet vitally important to healthy independent living for many individuals living with disability or chronic disease. Their ability to provide care in the home is increasing with the development of a variety of technology approaches. In this session, clinical needs related to rehabilitation and home exercise were discussed. Technologic advances that might address these needs were then
presented. Related issues and challenges are summarized in the following discussion points.

**Session Discussion Points**

- Secondary injuries experienced by caregivers should be studied further. Caregivers would rather have false alarms (ie, alerts even when there was not a fall) than worry that they missed a fall and that no one will know when help is needed. A backup plan is also needed. 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. The 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 (http://www.edc.gsp.hsp.pitt.edu/reach2/). It has been adopted by the VA and other agencies.
- 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, the mechanism is not yet clear, and which social networking modality might be successful is not known. More collaboration is needed between clinicians and social scientists. The evaluation process of Consumer Reports and the rating system of Amazon.com 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 platforms, such as smart phones, 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.

**WRAP-UP DISCUSSION**

Although the technologies discussed during this workshop hold a lot of promise for keeping people healthier and 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 1960s. More evidence of their comparative effectiveness and cost-effectiveness is needed. Although studies of efficacy and cost will likely be large, long, and costly, the evidence they yield is likely to encourage CMS and other payers to support the use of personal motion technologies in the home. As the United States health care system is heterogeneous, these studies will have to account for the care model used.

The field of technology development is also hampered by the current focus on single components as opposed to integrated systems. Integrated systems will require the development of standards and a common platform, but once these are developed, the market will serve to determine which systems are most useful.

Effectiveness studies would benefit significantly from leveraging existing care systems such as congregate housing and federally funded senior centers where seniors already receive assistance. The staff at these centers would be an asset to these studies by assisting with recruitment of study participants. In turn, study conclusions would be effectively reintroduced into real practice by having the care professionals implement findings in these communities. However, limited health care dollars and competition for them might turn out to be a barrier to leveraging existing resources. Staff at skilled nursing facilities and assisted living centers might feel threatened and be less willing to participate in such studies because they may feel that these technologies threaten their jobs by keeping people at home—and thus away from assisted living facilities—longer.

The development of successful personal motion technologies will require a great deal of collaboration between clinicians and technology, as well as synthesis of knowledge across disciplines. Some steps toward that goal would be the publication of research results in common journals, the sharing of findings through unified knowledge bases such as the clearinghouse on products and product development hosted by LeadingAge (www.leadingage.org), and the development of training programs to develop the next generation of multidisciplinary researchers.

The workshop closed with a reminder from the American Association of People with Disabilities that the design of independent-living technologies should ensure accessibility and usability by those who need them. These should be core values at the same level as efficacy and safety; otherwise these technologies will ignore the needs of 20% of the United States 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: RESOURCES**

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.


Other suggested resources include:

- Technology for Long-term Care: www.techforltc.org
- Abledata, an NIDRR-maintained comprehensive database of assistive technologies: www.abledata.com
- LeadingAge provides a clearinghouse on products and technologies open to the public: www.leadingage.org
- CMS provides some Medicare benefits for telehealth. More information can be found at: www.cms.gov/MLNProducts/downloads/TelehealthSrvcsFctsht.pdf
- Accessible design guidelines and standards from the United States Access Board: http://www.access-board.gov/gs.htm