U.S. Department of Health and Human Services
Assistant Secretary for Planning and Evaluation
Office of Disability, Aging and Long-Term Care Policy

REPORT TO CONGRESS:

AGING SERVICES TECHNOLOGY STUDY

June 2012

Office of the Assistant Secretary for Planning and Evaluation

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In particular, DALTCP addresses policies concerning: nursing home and community-based services, informal caregiving, the integration of acute and long-term care, Medicare post-acute services and home care, managed care for people with disabilities, long-term rehabilitation services, children's disability, and linkages between employment and health policies. These activities are carried out through policy planning, policy and program analysis, regulatory reviews, formulation of legislative proposals, policy research, evaluation and data planning.

This report was prepared under contract #HHSP23320095647WC between HHS's ASPE/DALTCP and the National Opinion Research Center. For additional information about this subject, you can visit the DALTCP home page at http://aspe.hhs.gov/_/office_specific/daltcp.cfm or contact the ASPE Project Officer, Hakan Aykan, at HHS/ASPE/DALTCP, Room 424E, H.H. Humphrey Building, 200 Independence Avenue, S.W., Washington, D.C. 20201. His e-mail address is: Hakan.Aykan@hhs.gov.

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This report was prepared under the leadership of the Office of Disability, Aging, and Long-Term Care Policy in the Office of the Assistant Secretary for Planning and Evaluation (ASPE) at the U.S. Department of Health and Human Services (DHHS), through a competitively awarded contract to NORC at the University of Chicago and the LeadingAge Center for Aging Services Technologies (CAST), with funding and close cooperation from the Office of the National Coordinator for Health Information Technology (ONC).

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ABSTRACT

Older adults, people with disabilities, and those who provide services and supports to these individuals utilize a variety of aging services technologies (ASTs) to achieve and maintain maximum physical function, to live as independently as possible, to study and learn, and to participate in and contribute to society. The potential benefits offered by these technologies are of great interest because of the aging of the U.S. population and the accompanying increase in caregiving responsibilities among family and friends, and because of the stresses being placed on the health-care system as a result of the increase in the number and complexity of chronically ill and disabled adults. This report presents findings from the Aging Services Technology Study, which was mandated in Section 13113(c) of the American Recovery and Reinvestment Act of 2009 (ARRA) (Public Law 111-5) as "a study of matters relating to the potential use of new aging services technology to assist seniors, individuals with disabilities, and their caregivers throughout the aging process." It provides a detailed discussion of ASTs related to eight care issues; a discussion of the interplay of ASTs with health information technology; and an exploration of barriers to the development and adoption of ASTs, including a discussion of potential strategies that can be implemented to address these barriers. The report provides a systematic framework for considering the existing evidence supporting the effectiveness of a diverse array of ASTs, information pertaining to ASTs that are under development, and those that are available outside of the U.S., thereby fulfilling the legislative mandates stipulated in ARRA.

EXECUTIVE SUMMARY

Introduction

Technology has become an indispensable aspect of modern life. In addition to common technologies such as computers and cellular phones that improve the efficiency and quality of our lives, technology can also support older adults and people of all ages with disabilities, as well as those who provide services and supports to these individuals. The potential benefits of these technologies are of particular relevance because of the aging of the U.S. population and the corresponding increase in the caregiving responsibilities among family and friends, and because of the stresses on the health-care system resulting from the increase in the number and complexity of chronically ill and disabled adults. Aging Services Technologies (ASTs) hold promise for addressing a number of key care issues that affect the elderly and individuals with disabilities, and their formal and informal providers of services and supports. The purpose of this report is to present findings from the Aging Services Technology Study, mandated in Section 13113(c) of the American Recovery and Reinvestment Act of 2009 (ARRA) as "a study of matters relating to the potential use of new aging services technology to assist seniors, individuals with disabilities, and their caregivers throughout the aging process."

For the purposes of Section 13113(c) of ARRA, ASTs are defined as any "health technology that meets the health-care needs of seniors, individuals with disabilities, and the caregivers of such seniors and individuals." This is a very broad definition that could include potentially thousands of technologies that are currently available or in development. To ensure that the Aging Services Technology Study is both comprehensive and systematic in addressing the legislative requirements for the study for different potential audiences, a framework for the study was developed that builds upon previous studies and utilizes a selected set of care issues. The care issues included in this study were chosen based on a review of published literature, input from experts in aging, disability, and technology, and feedback from a Technical Advisory Group that was convened for this study. This process resulted in a list of care issues that affect a significant number of people, are associated with significant costs, and have the potential to be improved through the use of non-pharmaceutical ASTs. For each care issue, the study reviews its prevalence and the magnitude of its associated personal, financial, and caregiving costs. Each chapter also reviews currently available ASTs that address problems associated with the care issue (including a synthesis of the evidence of their effectiveness in addressing these problems), examines ASTs that are under development, and analyzes the extent to which ASTs are available in other developed countries but not in the United States. The study also presents a separate discussion of the interplay of ASTs with health information technologies. In addition, it details barriers to development and adoption of ASTs and potential strategies for addressing them that are applicable to all care issues covered in this study.

Summary of Overall Findings

This study explores application of ASTs to a number of care issues that are highly relevant to older adults and people with disabilities. Like the care issues they address, these ASTs are numerous and varied. Some technologies that are currently available have single, straightforward functions, such as detecting falls; others, like activity monitoring systems, perform multiple functions. Further, although some ASTs are designed to support a single user (e.g. consumers, caregivers, providers), others have design features that support multiple users and help facilitate communication among them. Some ASTs, such as technology-enhanced wheelchairs and canes are variations on common appliances or assistive devices, while others are complex systems in which multiple technologies are integrated into a suite of supportive services aimed at preserving multiple aspects of independence.

In addition to the wide variety of existing ASTs, there are new technologies under development that are applicable to all of the care issues discussed in this report. Many of these emerging technologies offer improvements to existing products and technology-enhanced services. These improvements often involve modifications to functionality, design, or the interface between the technology and caregivers or providers. In contrast, many other ASTs under development are entirely new products that approach the provision of services and supports in novel, innovative ways.

There is substantial heterogeneity in the amount and quality of the available evidence supporting the efficacy and cost-effectiveness of the ASTs examined in this report. Some ASTs lack compelling evidence of their benefits simply because they are too new to have undergone thorough investigation. Other technologies have been studied more extensively, but with mixed results. A number of factors may be responsible for these mixed results, including an actual lack of efficacy, inadequate or inappropriate testing procedures, and small sample sizes. In addition, many of these studies approach cost-effectiveness simplistically, do not engage payers or involve aspects related to financial incentives. There are, however, a number of ASTs that have been studied with robust, reproducible results. For a great majority of ASTs, these results provide strong evidence of both clinical and economic benefits, suggesting that specific ASTs can help improve health outcomes, preserve individuals' ability to continue living independently in the community, improve care coordination, and reduce the cost of care. In some cases, ASTs can also improve the quality of life of informal caregivers by relieving certain physically and emotionally burdensome caregiving duties, and improve quality of care by increasing providers' access to accurate, timely, and relevant health information.

This study also examines the availability and use of ASTs outside of the United States. ASTs that are currently available in other countries are often similar or identical to those available in the U.S., but enjoy broader acceptance and penetration abroad, particularly in the European Union. This is due in large part to government initiatives to encourage AST adoption and use, such as increasing public awareness and available incentives, as well as efforts to build and maintain the infrastructure to support them.

The interface between health information technology (health IT) and ASTs that collect and can transmit important heath data offers additional promise for improved care that has the potential to benefit consumers, caregivers, and providers alike. Health IT ensures that the data can be properly shared and leveraged in the context of other health information. For example, when data generated by ASTs are incorporated into an electronic health record, the result is a permanent medical record that can be shared among providers and that offers a more complete view of patients' health and treatment history. Thus, the interplay of health IT and ASTs can facilitate communication, support clinical decision-making, and enhance quality of patient care, regardless of geographic location or institutional setting. Although this potential has been recognized by providers, AST developers, and other stakeholders, there are challenges associated with the AST-health IT interplay, mostly related to challenges associated with health IT development and implementation.

Development and adoption of ASTs is hampered by various important barriers. An important barrier is the widespread lack of awareness of ASTs, which results in underutilization among consumers, caregivers, and providers. Among those who are aware of these technologies, AST use is limited by concerns about evidence of effectiveness, stigma, privacy and security, usability, impact on workflow, difficulties with interoperability, liability, and affordability. Despite these challenges, all of these issues are being addressed gradually as ASTs garner increased attention among consumers, researchers, payers, and policy-makers alike. Indeed, this study finds a range of potential strategies that can address these barriers, spark AST innovation, and encourage adoption. These strategies include focused efforts to increase awareness and expand the AST consumer base and improve alignment of existing programs and incentives to encourage AST development and adoption.

Summary of Care Issues Findings

Falls

Falls often result from an unfavorable combination of physical, behavioral, and environmental factors. As a result, fall-related technologies address multiple fall risk factors. These include tools for fall risk assessment, prevention, and detection. ASTs are effective in fall assessment and prevention functions and, when combined with health IT solutions, they facilitate clinical decision-making and the planning of clinical interventions. Many fall detection devices successfully detect falls, but some are more effective and reliable than others in that they can generate alarms that can be acted upon by providers and caregivers. Fall-related technologies under development include canes and shoe insoles that collect data to assess fall risk, improved algorithms for calculating fall risk, sensory stimulation devices to improve balance, wireless devices that transmit fall alerts and the patient's location to a call center, smart phone applications for fall detection and alert transmission, and devices that detect falls in the home through vibrations in the floor. Although many European countries use technologies similar to those employed in the U.S., these devices have been integrated into existing care delivery systems more effectively in Europe and thus adoption is more widespread than in the U.S.

Chronic Disease Management

Most ASTs for chronic disease management address one or more issues that are central to successful disease management: 1) frequent monitoring; 2) communication and care coordination; and 3) promotion of effective and sustained self-care. These technologies include telehealth; remote patient monitoring devices that can be used to monitor, record, and transmit health information to physicians; and clinical decision support for physicians. Evidence supporting the efficacy of these technologies varies by device and health condition. For instance, while remote patient monitoring devices benefit patients with diabetes and heart failure, telehealth has yielded mixed results treating heart failure patients, but promising results for chronic obstructive pulmonary disease and hypertension. A number of innovative technologies for chronic disease management are under development. These include cloud-computing technologies, nanotechnology that allows physiological monitoring and data transmission through small devices like contact lenses, implantable monitors that overcome compliance issues, and artificial organs. There is little difference between chronic disease management technologies available in the U.S. and those available in other developed countries. However, in Canada and Europe, greater efforts have been made to promote adoption through investments in technology, demonstration projects, and utilization of the medical home model to provide continuity and efficiency of care.

Medication Management

Medication prescription and administration errors, non-adherence, side effects, and adverse drug interactions are challenges that can be addressed by medication management technologies. These technologies include electronic prescribing; computerized physician order entry; clinical decision support systems; telepharmacy; and devices that dispense medication, provide reminders, and in some cases monitor adherence. These technologies increase physician access to patients' medical histories and have been shown to reduce medication errors. Studies on telepharmacy show that telepharmacy may improve medication management. Evaluations of dispensing, reminding, and monitoring devices suggest these ASTs may improve adherence and lower rates of hospital and emergency room visits. Advances in medication management technology aim to enhance both patient adherence and safety using advanced reminding and/or dispensing functions; and provision of context-based reminders, including ascertainment and monitoring of medication ingestion and potential drug or food interactions. Several unique medication management technology projects are under way in the European Union, including mining hospital repositories for data to assess risks for, prevalence, and probable causes of adverse drug events; efforts to improve care and management by improving interoperability in Europe; and medication identification systems for the visually impaired.

Cognitive Impairments

Technologies that address cognitive impairments and decline include those focusing on prevention, detection, and intervention. Technology-enhanced prevention efforts typically focus on maintaining cognitive capacity through word games, social contacts, and other types of task-specific daily stimulation. Detection-oriented technologies include cognitive testing and home-based activity monitoring as well as advanced neuroimaging techniques. Interventions can involve technology-enhanced memory aids, GPS-based anti-wandering systems, and memory-targeted electronic games. Task-specific games tend to have limited benefits on long-term cognitive health, and the effectiveness of efforts to prevent depression and decline via social contact are as yet unproven. Technologies that detect cognitive impairments and decline are well-tested and effective in most cases, while intervention methods vary in their effectiveness. New technologies often enhance the capabilities of existing devices or systems, while others involve advanced home monitoring and data transmission. Some European countries leverage similar technologies but with a heavy emphasis on and government investment in “social alarms” (i.e., systems that provide various cognitive supports to patients and allow caregivers to monitor them remotely).

Sensory Impairments

ASTs addressing sensory impairments can be classified as intervention options, auxiliary and adaptive aids, technologies that address household responsibilities, and those focusing on navigation. Interventions related to hearing impairment include hearing aids, middle-ear implants, cochlear implants, and electric acoustic stimulation; vision-oriented technologies include lenses and magnification devices. Technologies that combine hearing and vision functions are also available. Auxiliary aids and adaptive equipment can also compensate for sensory loss. These include talking watches, phones, and electronic devices with large buttons. A number of technologies are available to facilitate computer use and reading among people with visual and hearing impairments, and devices that translate text to speech, amplify sound, and modify smart phones to aid the hearing-impaired are also currently available. ASTs that assist with navigation such as GPS units and technology-enhanced supports such as intelligent walkers and canes can help older adults with visual impairments retain functions that are critical for independent living. These technologies will benefit individuals with acquired sensory impairments due to aging, as well as children, youth, and adults with developmental and other disabilities. Innovative technologies are under development to address challenges associated with sensory impairment. These include surgical options (artificial retinas, and retinal and cochlear implants) as well as enhanced cell phones and other technologies. A particularly innovative effort in the European Union aims to address challenges in the home with a technology platform that integrates television, phone, and computers, and transmits audio signals to wireless hearing aids. A similar effort seeks to integrate devices and transmit visual information to smart phones.

Depression

A number of ASTs target depression-related problems such as challenges associated with diagnosis, lack of access to mental-health professionals and services that results in inadequate treatment, perceived stigma on the part of affected individuals, loss of motivation and sense of purpose, and social isolation. These technologies include telemental health applications, internet and social networking applications, computer-based monitoring and symptom questionnaires, wearable and embedded monitoring devices, and software- and internet-based games. All of these technologies are intended to increase social contacts and/or interactions with health-care providers, which can mitigate symptoms of depression. A number of technologies under development attempt to leverage the internet to decrease social isolation and loneliness, while others attempt to better identify symptoms of depression using voice recognition software and physiological symptom monitoring. Other countries are similarly focused on increasing social connectedness and contact with caregivers via the internet and integrated technology platforms in the home.

Mobility Impairments

ASTs that address mobility impairments include wheeled mobility equipment, mobility aids (e.g., chairs, canes, walkers), rehabilitative devices (e.g., aids to improve balance, walking, and posture), and multi-purpose devices (e.g., wheelchairs with additional lifting, stair climbing, and exercise functions). These devices are mostly well-recognized as safe and effective. Several technologies are currently under development that enhance the functionality of existing technologies to create "intelligent" mobility aids such as autonomous wheelchairs, smart/robotic walkers, and mobile robotic assistants, as well as improved rehabilitative devices. Similar efforts to create intelligent or enhanced mobility aids are under way in other countries. Scientists in Japan and Israel are designing robotic suits that increase users' strength and mobility with a combination of supportive braces and sensors that move the AST in concert with the users' natural body movements.

Functional Decline

Addressing the physical aspects of functional decline requires ongoing assessment of disability precursors, timely detection of events associated with functional decline, and effective interventions. Functional decline may be the result of aging or of developmental or acquired disabilities, or "functional limitations," such as muscular dystrophy or other neuromuscular diseases, ALS, and multiple sclerosis. Examples of ASTs that address these challenges include wearable devices (e.g., activity monitors that record gait, balance, physical activity, energy expenditure), passive monitoring systems (e.g., video- or sensor-based home monitoring that tracks sleep cycles, activity levels, falls, and/or changes in routine that may signal of illness), and interactive technologies (e.g., online symptom questionnaires, medication reminders, and wellness systems that involve patients and caregivers in symptom monitoring and care). Passive monitoring ASTs have the most robust testing and support in the literature, whereas evidence on the effectiveness of wearable devices and wellness platforms is more limited and mixed. Technologies under development focus on new approaches to detecting changes in gait and balance, stimulation of the extremities to improve gait and balance, systems that integrate multiple data streams in the home to identify declining function, and “smart” devices (e.g., walkers, canes, and home systems) with advanced functionalities to detect physical barriers in the environment, assist the user, and transmit an alert to caregivers in an emergency. International efforts to develop, validate, and promote use of assistive technologies in the home are widespread. European countries have made greater strides in the adoption and integration of certain ASTs into their health-care systems (e.g., social alarms, wearable activity monitors, physiological monitors, and telehealth). Robotic technologies under development in Japan and Israel (described in the mobility impairment chapter as well) are unique technologies that can also provide benefit to individuals with functional impairments in need of walking assistance.

Aging Services Technologies and Health Information Technology

If effectively integrated with one another, ASTs and health information technology (IT) can offer providers more complete health information that could enhance the quality of clinical care and decision-making. ASTs could interface with a range of health IT systems, including those that store and report information such as laboratory results to those that share information about patients across institutional and geographic boundaries, as well as systems that provide clinicians with real-time alerts and support decision-making based on all available patient information. Recent initiatives and policies encouraging the adoption of health IT, coupled with a growing awareness of the importance of both health IT and ASTs on the part of providers, patients (including children, youth, and adults with developmental disabilities), and caregivers suggest that the next few years may bring new opportunities to leverage these resources for the collective benefit of all stakeholders. For example, home-based medication management systems that can transmit data to the user's health-care provider can supplement data from electronic health records in a manner that gives clinicians detailed information on various parameters related to patients' medication adherence, information that would not otherwise be available. Telemental health strategies such as those employed by the Veterans Administration offer another example of the interface of ASTs and health IT in this area. Although meaningful efforts are under way to facilitate the interplay between health IT and ASTs, significant challenges remain before this goal is met, including important issues related to interoperability, privacy, and security.

Barriers to Aging Services Technology Adoption, Use, and Development

Despite the evidence supporting the utility of a number of ASTs, there are significant barriers to AST adoption and use. These barriers apply to all key stakeholders such as patients (including children, youth, and adults with developmental disabilities), providers, caregivers, payers, and those involved in technology development. Barriers involve issues related to lack of awareness and evidence of effectiveness, stigma, privacy and security concerns, usability and computer literacy, provider workflow, interoperability, liability, alignment of incentives, and investment. We recognize that lack of financing and financial incentives can constitute an obvious barrier to the development, adoption and use of ASTs. However, consideration of options for additional or alternative financing is not a focus of this study. Hence, this study focuses on strategies that could be reasonably implemented without major shifts or expansions in health-care financing. Potential strategies to address barriers to AST adoption and use include increased education of providers and consumers, an enhanced role for professional organizations in the dissemination of AST knowledge, effective use of privacy and security measures, testing and development that maximizes usability for both providers and consumers, as well as ongoing efforts to address interoperability.

Strategies to address AST development barriers include organizing the market through professional consortia that foster partnerships between technology companies, aging services providers, and researchers. Identification and promotion of business models that support the design and evaluation of these technologies offer additional opportunities to address these challenges. Large employers could play a role by encouraging their health insurance providers to redesign employee benefits programs to provide more incentives to employees who engage in technology-enabled self-management, fitness, or other wellness activities. Employers could also negotiate discounts with pre-screened technologies or services as part of their employee benefits packages. These approaches would result in increased demand for ASTs, thereby encouraging investment and development. Dissemination of evidence supporting AST adoption would ultimately increase the market size and encourage investments in the development of new and improved technologies that spur innovation.

Conclusions

While strategies designed to address most of the care issues covered in this report could be informed by additional research, existing evidence suggests that ASTs can and do help address a wide range of critical issues affecting the elderly, individuals of all ages with disabilities, and those who provide health and long-term care support and services to these groups. These issues are prevalent and costly in terms of health care dollars, caregiver burden, and patient quality of life. Technology developers are increasingly aware of consumer demands for not only clinical functionality, but also usability of the devices and the data for patients, caregivers, and providers. For payers, cost-effectiveness is an important consideration given the volume of patients in need, the aging of the population, and the growing health care costs in general. As such, there is widespread agreement among different stakeholders that new technologies must be clinically effective, user-friendly, and cost-effective so that they can be widely adapted and provide the full range of their potential benefits. New technologies are abundant and capitalize on the rapid technological advances that have arisen in the "computer age." There are also technologies under development that are as abundant and innovative, but some of these new technologies are in need of further testing, refinement, and validation.

The technologies under development outside the United States are, for the most part, similar or identical to the technologies under development in the United States, but there are key differences between national and international efforts in terms of level of AST adoption and the government's role in supporting and funding more-widespread adoption and development. There are important barriers to development, adoption, and use of ASTs, but effective strategies exist that can address many of these barriers within existing resource constraints. Therefore, even as the aging of the baby-boomer generation presents a new era of challenges related to public health needs and health-care system pressures, greater availability and adoption of ASTs holds great potential to help address these challenges.

INTRODUCTION

Purpose

The purpose of this report is to present findings from the Aging Services Technology Study, which was mandated in Section 13113(c) of the American Recovery and Reinvestment Act of 2009 (ARRA) (Public Law 111-5).

Background

Technology is an indispensable aspect of modern life, permeating almost every facet of our lives as individuals and societies. On a daily basis, people use smart phones to facilitate work and communicate with increased flexibility. Video-conferencing systems allow individuals to collaborate easily and more productively across long distances and technology-enhanced social networking helps to build and maintain connectedness. Apart from the benefits of these common technologies for improving the efficiency and quality of our lives, technology also holds great potential to support and improve the lives of older adults, people with disabilities of all ages, as well as formal and informal providers of the health and long-term services and supports (LTSS) that are commonly used among these vulnerable populations. In fact, older individuals and those with disabilities--both in the community as well as in other residential care settings--and those who provide services and supports to them, utilize a variety of technologies to achieve and maintain maximum physical function, live as independently as possible, study and learn, attain gainful employment, and participate in and contribute to society in a variety of ways. Global positioning systems that address wandering, passive call systems using sensor technologies, and intelligent wheelchairs are just a few examples of the applications of these technologies for older and disabled individuals.

Since the passage of the Americans with Disabilities Act in 1990 (ADA), the federal government has strengthened its commitment to improving the ability of people with disabilities of all ages to fully participate in major life activities. For instance, the New Freedom Initiative targeted removal of environmental barriers and increased access to assistive technologies. Many federal and state agencies contribute to similar efforts. The Interagency Committee on Disability Research coordinates and promotes cooperation among federal agencies in their disability research activities, and the Assistive Technology Act provides federal funding to states to develop assistive technology projects designed to meet the information and referral needs of people with disabilities. All of these efforts are important ways in which developmental disability and aging and disability issues can be addressed.

In addition, the federal government has sponsored initiatives to disseminate information on technologies that are geared toward older adults and people with disabilities. For instance, AbleData--an initiative that has been sponsored for more than two decades by the National Institute on Disability and Rehabilitation Research (NIDRR), is a database of information on almost 40,000 assistive technologies and rehabilitation equipment available to consumers, organizations, professionals, and caregivers in the United States (U.S.). The database contains descriptions of each product, including pricing and company information, as well as information on non-commercial prototypes and customized products. Technology for Long-Term Care, sponsored by the U.S. Department of Health and Human Services (HHS), developed a database of technologies for professionals engaged in planning, designing, managing, researching, and caregiving in LTC settings. This database, which is available to the public free of charge, focuses on technologies related to important care issues including fall prevention and detection, management of wandering, call systems, and incontinence management. It is designed to inform LTC providers and consumers about available technologies addressing these care issues.

There are also private initiatives (e.g., the Center for Aging Services Technologies or "CAST") that focus on aging services technologies (ASTs). These initiatives seek to increase awareness about available technologies and their value for individuals as well as for society as whole. They aim to highlight the importance of the intersection of aging services and health information technologies, and advocate for the establishment of standards that ensure interoperability between assistive and information technologies in the community and in various health-care settings, including LTC and acute and post-acute care.

Congress has recognized the potential of ASTs to benefit patients, providers, and caregivers as well as the interconnectedness of aging services and health information technologies. As a result, the ARRA required the Secretary of Health and Human Services to produce "a study of matters relating to the potential use of new aging services technology to assist seniors, individuals with disabilities, and their caregivers throughout the aging process." This study was required to include:

"(A) an evaluation of--

i. methods for identifying current, emerging, and future health technology that can be used to meet the needs of seniors and individuals with disabilities and their caregivers across all aging services settings, as specified by the Secretary;
ii. methods for fostering scientific innovation with respect to aging services technology within the business and academic communities; and
iii. developments in aging services technology in other countries that may be applied in the United States; and

(B) identification of--

i. barriers to innovation in aging services technology and devising strategies for removing such barriers; and
ii. barriers to the adoption of aging services technology by health care providers and consumers and devising strategies to removing such barriers."

For the purposes of Section 13113(c) of ARRA, ASTs are defined very broadly to include any "health technology that meets the health-care needs of seniors, individuals with disabilities, and the caregivers of such seniors and individuals." This is a very broad definition that could include potentially thousands of technologies that are currently available or in development. An organizational framework was needed to ensure that the Aging Services Technology Study (ASTS) is comprehensive and fully addresses the issues specified in the legislation. In its 2004 report titled, "Technology for Adaptive Aging," the National Research Council of the National Academies utilized a framework based on "high payoff areas in the development of technological devices that assist people who are aging normally, as well as those with disabilities and impairments." In this framework, six domains (communication, employment, health, learning, living environments, and transportation) were identified as important in the daily lives of older adults. The ASTS uses a similar approach that builds on the care issue framework developed under HHS's Technology for Long-Term Care.

The first step in establishing the framework for ASTS was identification and selection of care issues for inclusion in the study. For that purpose, a comprehensive environmental scan was conducted that included a review of published literature as well as reports and other documents produced by both government agencies and non-government stakeholders (such as the American Disability Association, American Medical Association, the National Alliance for Caregiving, and CAST, among many others); input from individual experts in aging, disability, and technology; and feedback from a Technical Advisory Group (TAG) that was convened specifically for this study. This environmental scan produced an initial list of a number of potential care issues to be addressed in this study. Criteria were also developed to guide the selection of the care issues that were most appropriate for the study since covering all of the issues in the initial list would have resulted in an unwieldy study that obscured key focus areas. These selection criteria included the following:

1. The care issue affects a significant proportion of older adults, people with disabilities or their health-care providers and caregivers;
2. The costs and burdens associated with the care issue are high; and
3. Meaningful and measurable improvements in the problems associated with the care issue can be achieved through the use of ASTs.

The TAG was convened in June 2010 and was composed of government and non-government experts with knowledge of a wide array of care issues affecting older adults and people with disabilities, as well as those with knowledge of the application of ASTs to these care issues and populations. Prior to this in-person meeting, TAG members had an opportunity to provide feedback on the framework developed for producing the

ASTS. With unanimous support on this framework, the TAG also reviewed the selection criteria and provided feedback on the initial list of care issues. This helped the ASTS project team select a manageable number of care issues to include in the study. In addition, the TAG contributed to the development of an outline for the ASTS to most effectively address the legislative requirements of the study within the ASTS framework. This outline provided structure to the report and its individual chapters.

The TAG recommended that, in addition to the initial set of selection criteria, the study address care issues for which ASTs can have an impact in multiple care settings. This would facilitate the delineation of technologies relevant to community-based care as well as institutional care; recognition of the distinctions among ASTs used for prevention, detection, and treatment; understanding of the level of infrastructure needed to support these ASTs; and assessment of whether the ASTs discussed in the chapters could be easily integrated into existing health IT systems. These recommendations were taken into account in the selection of the care issues, the outline for the study, and the scope of the research necessary to produce the study.

Using this expanded set of selection criteria and TAG recommendations, the following eight care issues were selected for inclusion in the ASTS: (1) falls prevention and detection; (2) chronic disease management; (3) medication management; (4) cognitive impairments; (5) sensory impairments; (6) depression; (7) mobility impairment; and (8) functional decline. Social isolation was initially included as an additional chapter. However, the ASTs associated with this care issue overlapped a great deal with other care issues, most notably depression. As a result, issues related to social isolation are addressed in the depression chapter and elsewhere, as appropriate.

Each of the care issue chapters uses a standard template to provide a consistent discussion of the issue and the AST-related topics associated with it. This approach facilitates comparisons of ASTs across the care issues included in the ASTS. Each chapter starts with a functional definition of the care issue, including a discussion of the specific challenges associated with it. The chapters then briefly discuss the prevalence of the problems associated with the care issue, and associated costs and burdens. After these contextual descriptions, the chapters present the findings that address the legislative requirements for this study.

The first component of these findings is a systematic presentation of available non-pharmaceutical technologies that address problems associated with the care issue, including a review of available evidence regarding effectiveness. The second component is a similar discussion focusing on emerging and future ASTs that are under development. The third and final component focuses on the experiences of other countries with respect to the development, adoption, and use of ASTs that address problems associated with the care issue. Collectively, these findings address study requirements listed under Sections 13113(c)(A)(i) and (iii) of ARRA.

Given that the interplay of ASTs and health information technology (IT) is critical to ensure the full functionality of a range of technologies, the interplay between ASTs and health IT is covered in a separate chapter. In order to address the requirements of Section 13113(c)(B), barriers to the development and adoption of ASTs are also discussed in a separate chapter that also details a range of potential strategies to address these barriers. These strategies include approaches to fostering innovation with respect to ASTs in the business and academic communities, thereby addressing the remaining ARRA requirement, Section 13113(c)(A)(ii).

The research necessary to produce the care issue chapters, the chapter describing the interplay between ASTs and health IT, and the chapter on barriers to AST development and adoption relied on a variety of published and unpublished sources, in addition to input from the TAG and other experts whom the project team consulted episodically. In order to ensure that readers can access the original sources on which the information in this report is based and to allow them to more readily expand upon the research presented here, a relatively long bibliography is included at the end of each chapter.

The report is organized as follows: Following this introduction are eight chapters covering the ASTs relevant to each of the eight selected care issues (Chapters 1-8). Chapter 9 then presents the interplay between ASTs and health IT and Chapter 10 discusses barriers to the development and adoption of ASTs and potential strategies for addressing them. The Conclusion then presents a synthesis of the key findings of the study.

CHAPTER 1: FALLS

1.1. Definition of Falls

Falls are broadly defined as an unintentional coming to the ground. According to one source (Tinetti, Speechley, and Ginter, 1988), a fall among the non-institutionalized older adult population could be more broadly defined as "an event which results in a person coming to rest unintentionally on the ground or lower level, not as a result of a major intrinsic event (such as a stroke) or overwhelming hazard." Additionally, with regards to older adults in institutionalized settings, another source defines a fall as "unintentionally coming to rest on the ground, floor, or other lower level, but not as a result of syncope or overwhelming external force" (Agostini, Baker, and Bogardus, 2001). Although falls are often called "accidents," they are not random events (Lord, Menz, and Sherrington, 2006). Rather, the causal processes that increase fall risk are varied and complex (for further discussion of the definition of falls among the elderly, see the 2008 Agency for Healthcare Research and Quality report referenced at the end of this chapter).

Falls are a major public health problem, particularly among older adults. Falls lead to considerable morbidity and mortality, much of which is preventable. Non-fatal falls can result in serious injuries such as hip fracture and traumatic brain injury, as well as less serious injuries such as bruises and lacerations. These injuries can have a direct and lasting impact on older adults' functioning and independence. In addition to the physical consequences of falling, many older adults who experience a fall develop profound fears of a future fall. Nearly 75 percent of people with a history of falls report that they are fearful of falling again (Rubenstein and Josephson, 2006). Even falls that do not result in serious injury can have a substantial psychological impact (Vellas et al., 1997). Fear of falling can lead older adults to reduce their level of physical activity, an approach to risk reduction that may unfavorably impact their health and independence and actually increase the risk of another fall (Vellas et al., 1997).

Falls typically result from a combination of physical, behavioral, and environmental factors, as well as a lack of adherence to safety precautions. Physical factors that increase the risk of falling include health conditions such as arthritis, stroke, diabetes, loss of visual acuity, aging of the inner ear--which can significantly affect balance--and proprioceptive loss of awareness and/or control of the limbs. These and other common chronic conditions increase fall risk in different ways. For example, strokes damage sensory, motor, and cognitive functions thereby limiting movement and increasing the risk of falling (Centers for Disease Control and Prevention, 2002). Decrements in visual acuity reduce awareness of the physical environment, including factors that may contribute to falls, such as uneven floors, rugs, or stairs. Older adults are at a particularly high risk of falls since many of the health-related factors that increase risk of falling also increase markedly with age, and older adults often experience more than one of these conditions concurrently. For example, visual impairment and arthritis both increase with age and contribute to fall risk, and it is common for older adults to have these conditions simultaneously. (Visual and mobility impairments are discussed in greater detail in Chapter 5 and Chapter 7, respectively.) Similarly, normal aging of the inner ear organs that affect balance can destabilize an older adult, and raise fall risk considerably when coupled with physical frailty, decrement in proprioception, or factors such as the presence of rugs and stairs.

Many of the chronic conditions that are common in old age are treated with prescription medications. Some of these medications have side effects or interact with other medications in ways that negatively affect coordination, reaction time, vision, and balance. These functions are necessary for fall avoidance and all can be compromised in the course of routine treatment for aging-related health conditions (Riefkohl et al., 2003).

Behavioral factors that increase risk of falling include a sedentary lifestyle and particularly a lack of exercise that promotes balance and maintenance of lower extremity strength. Fall risk can be favorably influenced with the addition specific behaviors to patients' interactions with their health-care providers. These behaviors include asking doctors to review medication lists for combinations of drugs that may increase fall risk, and vigilance in scheduling regular eye exams to ensure that prescriptions for corrective lenses are up to date.

Environmental factors that increase fall risk include loose carpets, high steps, and uneven or slippery surfaces. These hazards are of particular concern for older adults because they can interact with physical problems to compound the risk of falling. Although risk of falling can be reduced by safety precautions such as removing obstacles, modifying the living environment with improved lighting, and adding stair railings and bathroom grab-bars, these strategies are not fully utilized (Lord, Menz, and Sherrington, 2006). Use of assistive devices such as wheelchairs, walkers, canes among nursing home residents has also been shown to be an environmental risk factor for falls given the risks inherent in transfers and ambulation among those using these devices (Thapa et al, 1996; Spector et al, 2007).

A number of the technologies aimed at detecting and preventing falls, as well as mitigating the consequences of falling, target the specific challenges associated with falls and their risk factors, whether in the home or acute or long-term care settings. These include difficulties with assessing the risks of falling that stem from limited or inaccurate health information; the decreased physical activity that often accompanies aging and disability; the challenges associated with detecting high-risk movements and changes in gait and balance; and the lag time between the occurrence of a fall and receipt of appropriate medical attention. Existing fall-related technologies, as well as innovative technologies that are currently under development seek to address one or more of these fall-related problems (Frick et al., 2010).

1.2. Prevalence of Falls

Approximately one-third of adults age 65 and older experience a fall each year and 10 to 20 percent of older adults who fall sustain significant injuries that reduce mobility and independence, and increase the risk of institutionalization and mortality (Stevens et al., 2006). Data from the 2006 Behavioral Risk Factor Surveillance System show that approximately 5.8 million adults over 65 (15.9 percent of the over 65 population) experienced at least one fall in the previous three months. Of this group, 1.8 million people (31.3 percent) required medical attention or had at least one day of restricted activity as a result of the fall, and an estimated 15,802 adults over age 65 died as a result of fall-related injuries (Centers for Disease Control and Prevention, 2006). Adults who have fallen in the past are more likely than those who have not to fall again and to be admitted to a nursing home (Rubenstein and Josephson, 2006). These data underscore not only the high prevalence of falls among older adults, but also the exceptionally high risk among those with a history of falling.

Fall-related complications increase sharply with age, as does the likelihood of death due to these complications (Rubenstein and Josephson, 2002). In 2001, the rate of fall-related injuries for adults age 85 and older was four to five times the rate in adults age 65 to 74, and mortality was highest among those 85 and older. Although fall-related mortality is 49 percent higher among men than in women, women are 40 percent more likely than are men to sustain a non-fatal fall-related injury (Centers for Disease Control and Prevention, 2011d). Because women are more likely to survive a fall and to sustain non-fatal fall-related injuries, they are also more highly represented among older adults at risk of a recurrent fall.

Among older adults, falls are also the most common cause of non-fatal injuries, emergency department visits, and trauma-related hospital admissions. In 2009, approximately 2.2 million people age 65 and older were treated in emergency departments for fall-related injuries and more than 582,000 of these patients were subsequently admitted to the hospital (Centers for Disease Control and Prevention, 2009). Although falls are less common among young and middle-aged adults than they are among those over age 65, falls in middle age predict recurrent falls at older ages (Talbot et al., 2005**)**.

Older adults in skilled nursing facilities are twice as likely to fall as their community-dwelling counterparts (Rubenstein, 1997) due in large part to the high levels of functional impairment, multiple chronic conditions, and advanced age of many nursing home residents. It is critical to note that up to 25 percent of falls in institutional settings result in a moderate to severe injury or hospitalization (Rubenstein, Josephson, and Robbins, 1994; Doweido, 2000; Rubenstein, Powers, and MacLean, 2001; Hoskin, 1998). Moreover, the actual rate of falls in nursing homes is likely significantly higher than what is documented because many falls that occur in this setting are unreported (Rubenstein, Josephson, and Robbins, 1994), and thus it is difficult to estimate the true rates of injurious and non-injurious falls.

1.3. Costs and Burdens Associated with Falls

Falls are associated with substantial health-care spending. In 2000, fall-related costs totaled more than $19 billion, $179 million of which was due to fatal falls (Stevens et al., 2006), a figure representing over $28.2 billion in 2010 dollars (Centers for Disease Control and Prevention, 2011b). Another study reported that 9 percent of non-institutionalized older adults suffer fall-related medical conditions that incur an estimated $7.8 billion per year in direct medical costs (Carroll, Slattum, and Cox, 2005). In addition to the costs associated with falls themselves, a fall can exacerbate existing conditions and create new health problems that further threaten independence (Lach, 2010). For example, an older adult with diabetes who sustains a wrist fracture during a fall may encounter difficulties injecting insulin or preparing healthy food, which may in turn serve as a barrier to proper diabetes management. Similarly, an older person with knee arthritis who experiences a hip fracture may find it difficult to maintain a prescribed exercise regimen aimed at managing arthritis pain and maximizing joint flexibility.

Of the 300,000 hip fractures reported annually in the U.S., 55 percent result from a fall. These injuries incur an average of $58,120 in health-care costs in the first year following the fracture (Frick et al., 2010). In addition to financial costs, older adults who have fallen often make drastic lifestyle changes and incur costs associated with modifications of their living environments. For example, people who have fallen may install safety or supportive equipment in their homes in an effort to address new physical limitations resulting from the fall or to reduce the risk of a future fall (Stevens, 2005). Falls may also result in considerable indirect costs that are often borne by families or other informal caregivers of the person who experienced a fall. Examples of these costs include lost time from work on the part of the person who fell, the need for ongoing informal caregiving on the part of family, friends, and neighbors, and lost work time for these informal caregivers (Centers for Disease Control and Prevention, 2011b).

1.4. Available Fall Management Technologies and Evidence of Their Benefits

A report that reviewed the effectiveness of fall prevention interventions concluded that on average, targeted programs have the potential to reduce the risk of falls by 11 percent. This study found that interventions integrating clinical assessments such as those for gait, balance, and neurological functioning with behavioral strategies such as exercise could lower the risk of falling by 18 percent (RAND, 2003). Some studies also suggest that prevention strategies can effectively address fall risk factors such as improper medication management and depression (Stel et al., 2004). While some fall prevention strategies include “low-tech” or “non-tech” strategies such as securing rugs and installing grab-bars, others rely heavily on technology not only to prevent falls, but also to reduce both the impact once they occur and the risk of recurrent falls (RAND, 2003). Technology-based tools often take the form of health information technologies (health IT) that assist clinicians with risk assessment and prevention; technologies that help at-risk adults increase their levels of physical activity; technologies that alert professional staff or caregivers when someone is engaging in high-risk movements; and technologies that facilitate timely receipt of medical services when a fall has occurred.

The Role of Technology in Multi-Factorial Fall Management Interventions

The complex, interactive nature of fall risk suggests the need for a multi-factorial approach, where multiple intervention strategies are utilized to mitigate multiple risks simultaneously. These approaches might include strategies such as modifying the home environment (e.g., removal of loose carpets, installation of grab bars), ensuring that corrective lens prescriptions are up-to-date, and engaging in appropriate physical activity (Assistant Secretary for Planning and Evaluation, 2004). The most effective fall interventions are multi-factorial approaches that combine fall prevention strategies with coordinated care programs (Rubenstein and Josephson, 2006). One such intervention --which combined leg-strengthening and balance exercises, addressing home safety issues, vision and medication assessments, and consulting an occupational therapist--resulted in a 31 percent reduction in falls among the participants, older adults who had had a fall in the last 12 months (Clemson et al., 2004).

Despite the fact that effective methods for preventing falls and fall-related injuries are available, implementing effective programs remains a challenge (Nelson et al., 2004). One of the main challenges associated with successful implementation of these programs is the need to tailor the interventions to individual patients' health profiles, residential/care settings, and specific fall risk factors. For instance, an older individual with arthritis who lives in a home with staircases and who has no reliable source of primary care likely has a different set of fall risk factors than someone who has pronounced visual impairment and diabetic neuropathy and who resides in a single-level home. Similarly, a frail nursing home resident has different fall risk factors than someone who is temporarily hospitalized for a chronic medical condition and is taking multiple medications for both their acute and chronic complaints. To address the variation in fall risk profiles among different groups of individuals, one health system located in Massachusetts utilizes a toolkit that reviews each patient's risk of falling via their unique health record and then establishes a customized intervention program. Thus far, this system has been effective in reducing the rate of falls among hospitalized patients, specifically among older adults (adults age 65 and older) (Agency for Healthcare Research and Quality, 2009), and may prove effective in other care settings as well. There is no "one size fits all" strategy and some approaches are better suited for older adults in certain stages of life, persons with disabilities, those with specific chronic conditions, or particular care settings. Therefore, implementation of fall prevention technologies in isolation is unlikely to be effective at reducing falls. Rather, technology-focused interventions may be most beneficial if implemented in tandem with other environmental, behavioral, and clinical fall prevention strategies (Rantz et al., 2008).

Health IT-Based Technologies for Fall Risk Assessment and Fall Prevention

Health IT-based risk assessment and decision support systems use electronic health record (EHR) data to provide clinicians with up-to-date information on patients' health conditions, medications, and functional abilities. These systems can also include information on history of falls and fall risk factors. This comprehensive view of patients' risk factor profile enables providers to identify older adults at elevated risk of falling thereby allowing them to intervene before a fall occurs. Clinical decision support (CDS) systems use cumulative EHR data to alert providers when changes in fall risk factors occur and provide decision support to help clinicians manage risk. These technologies address problems associated with clinician access to relevant patient information on falls and fall risk factors, as well as the ability of the clinician to perform an informed assessment of fall risk. For example, when an older adult receives a prescription for a new medication, CDS systems may alert the prescribing clinician to contraindications that may increase fall risk and advise the physician to alter the medication or its dose to decrease the risk. In addition to features that help clinicians prevent patients from falling, these technologies can help clinicians implement post-fall interventions in accordance with best practices and evidence-based guidelines (Teigland et al., 2005). Examples of these interventions include switching to medications that pose less of a risk for falls and initiating exercise programs.

Published research has demonstrated that health IT-based fall risk assessments not only identify individuals who are at elevated risk for falls, but also facilitate appropriate decision-making and clinical intervention strategies for these patients. One study investigating fall risk assessment combined with preventive interventions (e.g., medication modification, strength training, vision adjustment, and blood pressure treatment) showed that compared with older adults receiving usual care, fall-related health-care utilization in the intervention group diminished by 11 percent. The same study showed that serious fall-related injuries were 9 percent lower in the group receiving the multi-factorial intervention that included fall-related health IT (Tinetti et al., 2008).

Another study evaluated a fall prevention toolkit that uses risk assessment to support a health IT application aimed at providing decision support at the patient's bedside. The toolkit includes bedside posters, patient education handouts, and alerts on fall prevention interventions that address the specific needs of each patient. This health IT-enabled intervention was integrated into existing workflow at four urban acute care hospitals and resulted in significant reductions in falls compared to usual care (Dykes et al., 2010). When interpreting the data on health IT-based interventions' impact on falls, it is important to note that benefits observed in one setting (e.g., an acute care hospital) may not translate to other settings where key issues such as workflow, availability of EHRs, patient profiles, and other factors may influence the degree to which these interventions can help (Schwendimann, De Geest, and Milisen, 2006). Nonetheless, there is evidence supporting the general ability of health IT to help clinicians prevent falls in high-risk populations by facilitating access to relevant information that helps in risk assessment and implementation of tailored interventions.

Activity-Focused Technologies for Fall Prevention

Fine motor activity monitoring technologies aim to prevent falls by observing movement, raising awareness on the part of both the user and clinicians to specific movements linked to falling, and encouraging physical activity. Newer activity monitoring strategies offer many improvements over traditional pedometers, which were originally designed to help the user track the number of steps taken during a typical day. Like traditional pedometers, newer devices are worn on the body, but can integrate sensors that measure acceleration and, in some cases, orientation relative to the ground. These assessments offer a more sophisticated view of ambulation as well as the body's position in space (Zhang et al., 2003). A recent review of wearable accelerometer-based activity monitors indicated that these devices are effective in measuring physical activity. Beyond quantifying activity levels, some devices can also measure sway with a moderate level of accuracy as well as cadence, stride length, stride regularity, and walking speed, all factors associated with risk of falling (Yang and Hsu, 2010). Given the associations among lack of physical activity and gait and speed abnormalities in elevating fall risk, advances in activity monitoring technology offer promise to older adults who wish to engage actively in self-monitoring to guard against these risks.

While some activity-focused technologies aim to prevent falls by promoting physical activity and alerting the user to changes in gait and balance, others alert caregivers to movements that may increase the risk of a fall. These types of technologies are most applicable to inpatient, long-term care, and congregate living settings where professional staff can respond quickly to alerts generated by these devices. However, they can also be used in the home where an informal caregiver could respond to an alert. Some of these devices are stationary and embedded in the patient's environment while others are worn by the patient.

Examples of embedded devices include bed and chair alarms that alert a caregiver or staff person when an at-risk individual gets up without assistance. These devices are equipped with a pressure-switch and/or weight-sensor systems that trigger an alarm when the user gets up unassisted (Bressler, Redfern, and Brown, 2011). This class of fall-prevention technologies is most common in hospitals and long-term care settings. One example of a wearable technology that serves this purpose is a credit-card size adhesive patch that is worn on the thigh. This device has a transmitter that sends a signal to a receiver in the patient’s room when the patient engages in high-risk activities or movements, thereby alerting a caregiver or staff person that assistance is needed. A nursing home-based study of the thigh patch showed a 91 percent overall reduction in falls among users. The same study indicated that the device was effective in reducing fall risk behavior among dementia residents, a group that has particular difficulty remembering to call for assistance before attempting to walk or transfer. Importantly, staff members’ and patients’ acceptance of the device was favorable (Kelly et al., 2002). Given the high rates of falls in nursing homes, technologies that are effective in reducing falls in this care setting may offer a particularly attractive return on investment.

The downside of alert devices is that they are effective in preventing falls only if staff or caregivers are available and respond quickly to the alarms, and if the alarms actually reflect the occurrence of a high-risk behavior or movement. A high rate of false alarms may eventually result in lack of response from caregivers thereby limiting the utility of this technology (Bressler, Redfern, and Brown, 2011). Moreover, response time on the part of staff--an issue related directly to the efficacy of these technologies whether they are worn on the body or not--depends largely on staffing levels. This consideration may limit the generalizability of individual studies because of differences in staffing levels across care settings. Nonetheless, in care settings where the availability of caregiver and/or staffing levels is sufficient, these devices may provide one useful element of a tailored, multi-factorial program to reduce falls and fall-related injuries, as long as the older person is willing to use the device if needed (Cheek, Nikpour, and Nowlin, 2005).

Technologies for Fall Detection

Older adults who receive help within one hour of a fall are nearly six times more likely to survive than those who wait longer for aid (Gurley et al., 1996). Personal emergency response systems (PERS) assist older adults in receiving prompt medical attention after a fall. Despite the dearth of published evidence on efficacy of PERS, survival statistics suggest that technologies that facilitate early detection of falls and rapid receipt of medical care can result in substantial mortality risk reduction, a key fall-related outcome (Otto and Chen, 2009). PERS may be especially helpful for older adults who live alone and are therefore more likely to have to wait for assistance if a fall occurs.

A PERS typically consists of three elements--a radio transmitter, a console, and an emergency response center that monitors calls. These systems are often divided into two classes: user-activated and automatic. User-activated PERS require the user to push a button in order to contact the emergency response center. Other PERS do not rely on the user, and contact the response center automatically if a fall occurs or, in some systems, appears imminent. Some automatic PERS detect falls using technologies such as accelerometers, gyroscopes, and tilt sensors. These data are integrated into a fall-detection algorithm that generates the alarm and notifies the call center (Rajendran, Corcoran, and Kinosian, 2008).

An important consideration with this and other devices that generate alarms involves sensitivity and specificity, terms that describe the degree to which these technologies generate false positives and false negatives. A technology that has a tendency toward false negatives may miss falls, provide the user with a false sense of security, and result in higher costs due to delayed receipt of medical services (LeadingAge CAST, 2007). On the other hand, technologies that generate false positives may result in unnecessary caregiver burden, the potential for unnecessary dispatching of emergency medical service personnel (and its associated costs), and ultimately, user fatigue. One study of accelerometer-based fall detectors found that a head-worn device had a particularly high level of sensitivity and specificity in detecting falls. Moreover, this device performed more accurately than commercially available detectors worn at the hip or wrist, especially when the body was not lying horizontally after a fall. For example, a fall that occurs on the stairs may not trigger a waist-worn alarm because the body remains partially upright, whereas a device worn on the head would be more likely to generate an alarm in this situation (Lindemann et al., 2005). Issues concerning sensitivity and specificity are not limited to accelerometers. Devices that rely on gyroscopes and tilt sensors can also generate false negatives in situations such as a fall that occurs on the stairs (Li et al., 2009). Correcting this deficiency involves increasing the sensitivity of these devices or, as in the head-worn detector, changing where on the body the device is worn.

A fundamental aspect of wearable fall alarm technologies is that the user must wear the device to receive its benefit, thus making efficacy dependent on user compliance. Compliance can be challenging for older adults, and those with cognitive or physical disabilities may experience particular challenges. For example, an older adult with mild cognitive impairment who forgets to put their device back on after bathing will not benefit from the technology if a fall occurs on a slippery bathroom floor (LeadingAge CAST, 2007). For some older adults, perceived stigma may also hinder the adoption of wearable devices, particularly if the device is visible to others (Srp and Vajda, 2010).

Unlike wearable technologies, fall detection sensors that are embedded in the environment do not require user compliance beyond the granting of permission for the device to be installed and monitored (Naditz, 2009). Although the primary purpose of this type of system is to detect falls, it can also contribute to fall prevention by identifying fall risk factors such as declining mobility (Rajendran, Corcoran, and Kinosian, 2008). These systems use multiple technologies such as motion sensors, video cameras, and floor vibration sensors to detect falls and alert caregivers, a call center, or emergency services. In a pilot study in an assisted-living facility, motion sensors were used to alert staff about possible falls when the user's motion data patterns deviated from what was expected. In this study, the sensor technology successfully detected falls, but false alarms also occurred with some frequency (Alwan et al., 2006).

Video-based systems enable caregivers to monitor users remotely and respond quickly to falls. One study of a smart home system that included video monitoring capabilities showed that older adults perceived fall detection to be an important function of the system and did not feel video technology interfered with their routine activities (Demiris et al., 2006). Despite acceptance by older adults, drawbacks to video monitoring systems include cost and the perception among some observers that video monitoring may be an invasion of privacy (Miskelly, 2001). Modifications designed to address privacy concerns have been introduced such as rendering images anonymous or altering images into "blobs" that show shape, posture, and motion rather than clear, identifiable images (Naditz, 2009).

Although the evidence base supporting the benefits of sensor-based systems for fall detection and prevention continues to grow, there are few large-scale studies assessing the effectiveness of these technologies.

1.5. Fall Technologies Under Development

One example of a fall prevention technology that is currently under development is the smart cane system. In addition to providing physical support, the smart cane integrates a sensor that detects and measures motion, rotation, force, strain, and contact. The device has wireless connectivity through Bluetooth or Wi-Fi, which streams data in real time to the user's personal data devices. The data device can then analyze the data and generate trending reports to a clinician, thereby facilitating detection of heightened fall risk and initiation of appropriate interventions. The system aims to reduce falls and fall-related injuries through continuous monitoring of mobility, classification of cane use patterns, and prediction of unfavorable outcomes (Wu et al., 2008).

Evolving fall management technologies are also focusing on data models that predict falls using mathematical algorithms to assess individuals' risk factor profiles (Trafton, 2008). These algorithms use experimental measurements data and individual threshold levels for key movements and postures, which can in turn quantify risk of falls (Li et al., 2009). Other researchers are developing shoe insoles that analyze foot pressures in a manner that provides information on risk factors such as balance (Trafton, 2008). Ultimately, this technology may enable clinicians to correct balance problems before a fall occurs. Another innovative fall prevention technology involves provision of sensory stimulation to the feet when patients lose their balance. This technology builds on research showing that loss of peripheral sensation increases gait variability and risk of falling. Applying stimulation to the soles of the feet may reduce the risk of falls by improving balance and reducing variability in gait (Galica et al., 2009). This technology may eventually benefit individuals who experience neurological problems that increase the risk of falls, including those with complications from stroke and diabetes (Harry et al., 2005).

For falls that result from balance-related problems, vestibular prostheses may eventually be available. Currently, external head-mounted and implantable prostheses are under development to address severe disruptions to the vestibular (balance) system of the inner ear (e.g., Ménière's Disease). One device involves a head-mounted component to detect head and eye movement, translate this movement into electrical signals, and transmit these impulses to electrodes implanted within the ear's vestibular organs (the semicircular canals). The electrodes then stimulate the vestibular organs and an impulse is transmitted to the brain that creates a sense of balance and bodily orientation in space. Thus far, this device has been tested only in animals, but it is being tested and refined for the eventual treatment of humans (Della Santina, Migliaccio, and Patel, 2007). Another implantable device, which differs in design and implantation technique, is being tested in different species of monkeys. This device is a modified cochlear implant that is implanted in a way that avoids the disruption to hearing that vestibular prosthesis can cause (Bierer et al., 2012). Although these devices are in the early stages, they have the potential to successfully mitigate fall risk in humans with age-, illness-, or trauma-related balance problems.

Other emerging technologies build on existing wearable and user-activated fall detection systems that are already available and on the market. New features incorporate additional elements such as cellular communications modules. For example, one cell phone-based system under development is equipped with an accelerometer for automatic fall detection that alerts an operator in an emergency call center who then contacts the caregiver or visits the home. Additional innovations in falls detection and prevention include establishing the location of the user through global positioning and dispatching of emergency services to that location.

Floor-based vibration detectors are another monitoring technology that can support fall detection without the privacy concerns associated with video monitoring. This technology was developed following the observation that vibrations generated from falls differ from those associated with walking or other daily household activities. These systems use a floor-based sensor to evaluate vibration patterns and, when patterns match those associated with a fall, the system generates an alert. Challenges remain with these technologies. For example, this approach is effective in detecting falls to the ground, but is less able to detect falls to the knees (Rimminen et al., 2010).

Additional innovative technologies are embedded in routine devices, non-invasive, and easy to use. For example, researchers are developing an alert system using an accelerometer that is built into an Android-based smart phone. After a fall, this system automatically routes a call to the user's phone and prompts a response. If the user fails to respond, the system will contact family or friends with an alert that a potential fall has occurred. If there is no response to that communication, the system contacts emergency services and relays the user's location using its global positioning capability. Two benefits of this system are its low cost and ease of implementation into commonly used platform (Sposaro and Tyson, 2010).

1.6. Experiences of Other Countries with Fall Technologies

Many European countries support coordinated care delivery that encourages development and adoption of fall prevention and detection technologies. For instance, the United Kingdom (U.K.) developed a National Framework Agreement on Telecare to support the public delivery of telecare services, including fall detection services. Social services agencies in the U.K. also use PERS, fall detectors, and passive monitoring systems (Chubb Community Care, 2010). A consortium of European organizations has partnered to advance fall management technologies for older adults. Many of the technologies that this consortium focuses on are similar to those being developed in the U.S., and they focus on similar problems underlying fall risk.

References

Agency for Healthcare Research and Quality (2008). Patient safety and quality: An evidence-based handbook for nurses. Chapter 10. Rockville: U.S. Department of Health and Human Services. Publication No.: 08-0043. http://www.ncbi.nlm.nih.gov/books/NBK2651/. Accessed April 2, 2012.

Agency for Healthcare Research and Quality (2009). Fall prevention toolkit facilitates customized risk assessment and prevention strategies, reducing inpatient falls. Rockville, M.D.: U.S. Department of Health and Human Services. http://www.innovations.ahrq.gov/content.aspx?id=3094. Accessed April 2, 2012.

Alwan, M., Dalal, S., Mack, D., Kell, S., Turner, B., Leachtenauer, J., Felder, R. (2006). Impact of monitoring technology in assisted living: outcome pilot. Institute of Electrical and Electronics Engineers Transactions on Information Technology in Biomedicine, 10(1), 192-198.

Bierer, S.M., Ling, L., Nie, K., Fuchs, A.F., Kaneko, C.R.S., Oxford, T., Nowack, A.L., Shepherd, S.J., Rubinstein, J.T., Phillips, J.O. (2012). Auditory outcomes following implantation and electrical stimulation of the semicircular canals. Hearing Research, 287, 51-56.

Bressler, K., Redfern, R.E., Brown, M. (2011). Elimination of position-change alarms in an Alzheimer's and dementia long-term care facility. *American Journal of Alzheimer's Disease and Other Dementias*, 26(8), 599-605.

Carroll, N.V., Slattum, P.W., Cox, F.M. (2005). The cost of falls among the community-dwelling elderly. *Journal of Managed Care Pharmacy,* 11(4), 307-316.

Centers for Disease Control and Prevention. (2002). Preventing falls: How to develop community-based fall prevention programs for older adults. Atlanta, G.A.: U.S. Department of Health and Human Services. http://www.cdc.gov/HomeandRecreationalSafety/Falls/preventfalls.html#DevCommunityPrg. Accessed April 2, 2012.

Centers for Disease Control and Prevention. (2006) Fatalities and injuries from falls among older adults -- United States, 1993-2003 and 2001-2005. Atlanta, G.A. U.S. Department of Health and Human Services. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5545a1.htm. Accessed May 24, 2012.

Centers for Disease Control and Prevention, National Center for Injury Prevention and Control (2009). Web-based Injury Statistics Query and Reporting System (WISQARS). http://www.cdc.gov/ncipc/wisqars. Accessed May 28, 2012.

Centers for Disease Control and Prevention. (2011a). Falls in nursing homes. Atlanta, G.A.: U.S. Department of Health and Human Services. http://www.cdc.gov/HomeandRecreationalSafety/Falls/nursing.html. Accessed April 2, 2012.

Centers for Disease Control and Prevention. (2011b). Cost of falls among older adults. Atlanta, G.A.: U.S. Department of Health and Human Services. http://www.cdc.gov/HomeandRecreationalSafety/Falls/fallcost.html. Accessed April 2, 2012.

Centers for Disease Control and Prevention. (2011c). Falls among older adults: An overview. Atlanta, G.A.: U.S. Department of Health and Human Services. http://www.cdc.gov/HomeandRecreationalSafety/Falls/adultfalls.html. Accessed April 2, 2012.

Centers for Disease Control and Prevention. (2011d). Web-based injury statistics query and reporting system (WISQARS). Atlanta, G.A.: U.S. Department of Health and Human Services. http://www.cdc.gov/injury/wisqars/index.html. Accessed April 2, 2012.

Cheek, P., Nikpour, L., Nowlin, H.D. (2005). Aging well with smart technology. *Nursing Administration Quarterly,* 29(4), 329-338.

Chubb Community Care (2010). 70 Degrees Verso Fall Detector. http://www.chubbcommuitycare.co.uk/products/info/70-degree-verso-fall-detector/. Accessed April 2, 2012.

Clemson, L., Cumming, R. G., Kendig, H., Swann, M., Heard, R., Taylor, K. (2004). The effectiveness of a community-based program for reducing the incidence of falls in the elderly: a randomized trial. *Journal of the American Geriatrics Society*, 52(9), 1487-1494.

Della Santina, C.C., Migliaccio, A.A., Patel, A.H. (2007). A multi-channel semicircular canal neural prosthesis using electrical stimulation to restore 3D vestibular sensation. IEEE Transactions on BioMedical Engineering, 54(6), 1016-1030.

Demiris, G., Skubic, M., Rantz, M., Keller, J., Aud, M., Hensel, B., He, Z. (2006). Smart home sensors for the elderly: A model for participatory formative evaluation. Institute of Electrical and Electronics Engineers, Engineering in Medicine and Biology Society, International Special Topic Conference on Information Technology in Biomedicine, 1-4.

Doweiko D. (2000). Prevention program cut patient falls by 10%. Hospital Case Management, 8(38), 43-44.

Dykes, P.C., Carroll, D.L., Hurley, A., Benoit, A., Lipsitz, S., Benoit, A., Chang, F., Meltzer, S., Tsurikova, R., Zuyov, L., Middleton, B. (2010). Fall prevention in acute care hospitals. *Journal of the American Medical Association,* 304(17), 1912-1918.

Frick, K., Kung, J., Parrish, J., Narrett, M. (2010). Evaluating the Cost-Effectiveness of Fall Prevention Programs that Reduce Fall-Related Hip Fractures in Older Adults. *Journal of American Geriatrics Society,* 58(1), 136-141.

Galica, A.M., Kang, H.G., Priplata, A.A., D'Andrea S.A., Starobinets, O.V., Sorond, F.A., Cupples, L.A., Lipstiz, L.A. (2009). Subsensory vibrations to the feet reduce gait variability in elderly fallers. *Gait & Posture,* 30(3), 383-387.

Gurley, R.J., Lum, N., Sande, M., Lo, B., Katz, M.H. (1996). Persons found in their homes helpless or dead. *New England Journal of Medicine,* 334(26), 1710-1716.

Harry, J.D., Niemi, J.B., Priplata, A.A., Collins, J.J. (2005). Balancing act: Noise based sensory enhancement technology. *Institute of Electrical and Electronics Engineers: Spectrum,* 42(4), 36-41.

Hoskin A.F. (1998). Fatal falls: trends and characteristics. *Statistical Bullitin*, 79(2), 10-5.

Kelly, K.E., Phillips, C.L., Cain, K.C., Polissar, N.L., Kelly, P.B. (2002). Evaluation of a nonintrusive monitor to reduce falls in nursing home patients. *Journal of the American Medical Directors Association,* 3(6), 377-382.

Lach, H. (2010). The costs and outcomes of falls: What's a nursing administrator to do? *Nursing Administration Quarterly,* 34(2), 147-155.

LeadingAge Center for Aging Services Technologies (CAST) (2007). State of technology in aging services. http://www.leadingage.org/uploadedFiles/Content/About/CAST/Resources/State_of_Technology_Report.pdf. Accessed April 4, 2012.

Li, Q., Stankovic, J.A., Hanson, M., Barth, A., Lach, J., Zhou, G. (2009). Accurate, fast fall detection using gyroscopes and accelerometer-derived posture information. 2009 International Workshop on Wearable and Implantable Body Sensor Networks, Institute of Electrical and Electronics Engineers Computer Society, 138-143.

Lindemann, U., Hock, A., Stuber, M., Keck, W., Becker, C. (2005). Evaluation of a fall detector based on accelerometers: A pilot study. *Medical & Biological Engineering & Computing,* 43(5), 548-551.

Lord, S.R., Menz, H.B., Sherrington, C. (2006). Home environment risk factors for falls in older people and the efficacy of home modifications. *Age and Ageing,* 35(2), 55-59.

Miskelly, F.G. (2001). Assistive technology in elderly care. *Age and Ageing,* 30(6), 455-458.

Naditz, A. (2009). Still Standing: Telemedicine Devices and Fall Prevention. *Telemedicine Journal and E-Health: The Official Journal of the American Telemedicine Association*, 15(2), 137-141.

Nelson, A., Powell-Cope, G., Gavin-Dreschnack, D., Quigley, P., Bulat, T., Baptiste, A.S., Applegarth, S., Friedman, Y. (2004). Technology to promote safe mobility in the elderly. *The Nursing Clinics of North America,* 39(3), 649-671.

Office of the Assistant Secretary for Planning and Evaluation (2004). The effect of reducing falls on long-term care services: Washington, D.C.: U.S. Department of Health and Human Services. http://aspe.hhs.gov/daltcp/reports/fallexpfr.htm. Accessed April 2, 2012.

Otto, C.A., Chen, X. (2009). Automated fall detection: Saving senior lives one fall at a time. *Caring,* 28(3), 44-46.

Rajendran, P., Corcoran, A., Kinosian, B. (2008). Falls, fall prevention, and fall detection technologies. In M. Alwan, R, Felder, *Eldercare Technology for Clinical Practitioners,* 187-202. New York City, New York: Humana Press.

RAND (2003). Evidence report and evidence-based recommendations: Fall prevention interventions in the medicare population. http://www.rand.org/pubs/reprints/RP1230.html. Accessed April 2, 2012.

Rantz, M.J., Aud, M.A., Alexander, G., Wakefield, B.J., Skubic, M., Luke, R., Anderson, D., Keller, J. (2008). Falls, technology, and stunt actors: New approaches to fall detection and fall risk assessment. *Journal of Nursing Care Quality*, 23(3), 195-201.

Riefkohl, E.Z., Bieber, H.L., Burlingame, M.B., Lowenthal, D.T. (2003). Medications and falls in the elderly: A review of the evidence and practical considerations. *Pharmacy and Therapeutics,* 28(11); 724-733.

Rimminen, H., Lindstrom, J., Linnavuo, M., Sepponen, R. (2010). Detection of falls among the elderly by a floor sensor using the electric near field. *Institute of Electrical and Electronics Enginneers, Transactions on Information Technology in Biomedicine,* 14(6), 1475-1476.

Rubenstein, L.Z., Josephson, K.R., Robbins, A.S. (1994). Falls in the nursing home. *Annals of Internal Medicine*, 121(6), 442-51.

Rubenstein, L.Z. (1997). Preventing falls in the nursing home. *Journal of the American Medical Association,* 278(7), 595-596.

Rubenstein L.Z., Powers C, MacLean C. (2001). Quality indicators for the management and prevention of falls and mobility problems in vulnerable elders. *Annals of Internal Medicine*, 135(8), 686-93.

Rubenstein, L.Z., Josephson, K.R. (2002). The epidemiology of falls and syncope. *Clinics in Geriatic Medicine,* 18(2), 141-158.

Rubenstein, L.Z., Josephson, K.R. (2006). Falls and Their Prevention in Elderly People: What Does the Evidence Show? *The Medical Clinics of North America,* 90(5), 807-824.

Schwendimann, R., De Geest, S., Milisen, K. (2006). Evaluation of the morse fall scale in hospitalized patients. *Age and Ageing,* 35(3), 311-313.

Spector, W., Shaffer, T., Potter, D.E., Correa-de-Araujo, R., Limcangco, M. (2007). Risk Factors Associated with the Occurrence of Fractures in U.S. Nursing Homes: Resident and Facility Characteristics and Prescription Medications. *Journal of the American Geriatrics Society*, 55(3): 327-333.

Sposaro, F., Tyson, G. (2010). Geriatric medical application suite on a sweet phone. 1st AMA-Institute of Electrical and Electronics Engineers, Medical Technology Conference on Individualized Healthcare, 21-23.

Srp, A., Vajda, F. (2010). Possible techniques and issues in fall detection using asynchronous temporal-contrast sensors*. Electrical and Electronic Engineering,* 127(7-8), 223-229.

Stel, V.S., Smit, J.H., Pluijim, S.M.F., Lips, P. (2004). Consequences of falling in older men and women and risk factors for health service use and functional decline. *Age and Ageing,* 33(1), 58-65.

Stevens, J.A. (2005). Falls among older adults: Risk factors and prevention strategies. *Journal of Safety Research,* 36(4), 409-411.

Stevens, J.A., Corso, P.S., Finkelstein, E.A., Miller, T.R. (2006). The costs of fatal and nonfatal falls among older adults. *Injury Prevention,* 12(5), 290-295.

Talbot, L.A., Musiol, R.J., Witham, E.K., Metter, E.J. (2005). Falls in young, middle-aged, and older community dwelling adults: Perceived cause, environmental factors, and injury. *BMC Public Health*, 18(5)**,** 86.

Teigland, C., Gardiner, R., Li, H., Byrne, C. (2005*).* Clinical informatics and its usefulness for assessing risk and preventing falls and pressure ulcers in nursing home environments. In Henriksen K., Battles, J.B., Marks, E.S., Lewin, D.I. *Advances in Patient Safety: From Research to Implementation,* Vol. 3, 69-85.

Thapa, P.B., Brockman, K.G., Gideon, P. Fought, R.L., Ray, W.A. (1996). Injurious falls in nonambulatory nursing home residents: A comparative study of circumstances, incidence, and risk factors. *Journal of the American Geriatrics Society*, 44(3):273-278.

Tinetti, M.E., Baker, D.I., King, M., Gottschalk, M., Murphy, T.E., Acampora, D., Carlin, B.P., Leo-Summers, L., Allore, H.G. (2008). Effect of dissemination of evidence in reducing injuries from falls. *The New England Journal of Medicine,* 359(3), 252-261.

Tinetti, M.E., Speechley, M., Ginter, S.F. (1988). Risk factors for falls among elderly persons living in the community. *New England Journal of Medicine,* 319(26), 1701-1707.

Trafton, A. (2008). Balance problems? Step into the iShoe. MIT News. http://web.mit.edu/newsoffice/2008/i-shoe-0716.html. Accessed April 2, 2012.

Vellas, B.J., Wayne, S.J., Romero, L.J., Baumgartner, R.N., Garry, P.J. (1997*).* Fear of falling and restriction of mobility in elderly fallers. *Age and Ageing,* 26(3), 189-193.

Wu, W., Au, L., Jordan, B., Stathopoulos, T., Batalin, M., Kaiser, W., Vahdatpour, A., Sarrafzadeh, M., Fang, M., Chodosh, J. (2008). The SmartCane system: An assistive device for geriatrics. 3rd International Conference on Body Area Networks, 1-4.

Yang, C.-C., Hsu, Y.-L. (2010). A review of accelerometry-based wearable motion detectors for physical activity monitoring*. Sensors,* 10(8), 7772-7788.

Zhang, K., Werner, P., Sun, M., Pi-Sunyer, F.X., Boozer, C.N. (2003). Measurement of human daily physical activity. *Obesity Research*, 11(1), 33-40.

CHAPTER 2: CHRONIC DISEASE MANAGEMENT

2.1. Definition of Chronic Disease Management

Chronic diseases are conditions that generally last at least one year and limit patients' self-care, independence, and social interactions. These conditions often require ongoing medical treatment (Perrin et al., 1993). Lack of appropriate chronic disease management contributes to impairment and functional limitations and can result in disability and institutionalization (Verbrugge and Jette, 1994). Diabetes is one example of a chronic condition that is common among older adults in the U.S. and for which clear management guidelines are well-established. Without proper management, diabetes results in a number of well-recognized vascular and neuropathic complications, including retinopathy, renal dysfunction, and neuropathy. Data from the Centers for Disease Control and Prevention highlight the contribution of diabetes to the risk of heart disease and stroke (Centers for Disease Control and Prevention, 2007a). All of these unfavorable outcomes contribute to disability, loss of independence, and increased health-care costs, and all can be mitigated with appropriate management.

Chronic disease management is a strategy for coordinating health care for populations with conditions that require patients to provide significant self-care (Continuum Care Alliance, 2012). Successful chronic disease management strategies address three fundamental issues: (1) the need for frequent monitoring of physiologic disease indices (e.g., blood pressure, blood glucose, weight); (2) the need for communication and care coordination among health-care professionals; and (3) the need for active and sustained self-care on the part of the patient (Friedewald and Pion, 2001). Because of their high prevalence, cost, and impact on morbidity and mortality, five conditions have become the focus of considerable chronic disease management efforts. These include heart failure (HF), diabetes, asthma, chronic obstructive pulmonary disease (COPD), and hypertension.

Despite the ability to define specific elements of successful chronic disease management programs, there are a number of practical challenges associated with meeting the goals of these programs. Some of these challenges are relevant to health-care professionals who care for people with chronic conditions while others apply to patients and caregivers. Challenges for health-care providers include difficulties associated with access to high-quality physiologic information and processing, transmitting, storing, and synthesizing this information in a manner that facilitates informed decision-making. Other challenges for health-care professionals involve securing access to patient health information between office visits, particularly among older and disabled patients who have difficulty leaving their homes, delivering appropriate health education and support materials, and monitoring responses to short- and long-term interventions. Problems with chronic disease management encountered by patients include the absence of timely feedback on existing self-management efforts;

lack of access to health-care professionals between office visits; and the absence of the reminders, ongoing education, and encouragement that are often necessary to ensure maintenance of appropriate self-management practices. Caregivers of chronically ill individuals also often experience diverse challenges associated with access to real-time information on patients' status and the absence of guidance on how to assist patients in self-management efforts (AARP, 2011). A number of currently available and evolving technologies seek to improve chronic disease management by addressing one or more of these problems.

2.2. Prevalence of Selected Chronic Conditions

Chronic diseases, including those discussed in this chapter, are the primary cause of more than 70 percent of all deaths in the U.S. Although chronic conditions occur in all age groups, their frequency increases with age. Eighty percent of Americans over the age of 65 have at least one chronic condition. Chronic diseases are the leading cause of death among older adults, and are responsible for 61 percent of all deaths in this age group (Centers for Disease Control and Prevention, 2007b). With the number of U.S. adults age 65 and older projected to reach 72 million by the year 2030 (Census Bureau, 2008), the number of Americans with chronic diseases is also expected to increase. The remaining sections of this chapter provide an overview of HF, diabetes, asthma, COPD, and hypertension and describe how current and emerging technologies may help providers, patients, and caregivers engage in better management of these conditions.

Heart Failure

HF is a disabling and costly condition characterized by weakness of the heart muscle. Approximately 5.3 million Americans have HF, 30 percent of whom have moderate to severe HF. Among people with HF, 80 percent are 65 years of age or older (Moser and Mann, 2002). There are more than one million HF-related hospital admissions each year, and HF is the leading cause of hospitalization among people over 65 years old (Krumholz et al., 2000). In addition, the prevalence of HF is increasing due in large part to the increasing number of older adults, as well as improved survival following acute cardiac events (which leads to more cases of HF among persons who would previously have died from these events) (Roger et al., 2004). According to the CDC, heart failure was a contributing cause of death for nearly 283,000 Americans in 2006 (Lloyd-Jones et al., 2010).

Diabetes

Diabetes is a heterogeneous set of conditions characterized by abnormalities of glucose metabolism that result in elevated blood glucose. About 25.8 million Americans, or 8 percent of the population, have diagnosed diabetes, and many more have diabetes that remains undiagnosed (Centers for Disease Control and Prevention, 2011). Diabetes is present in nearly 32 percent of Americans age 65 and over (Cowie et al., 2009), according to some estimates, and 27 percent according to others (Centers for Disease Control and Prevention, 2011). Half of diagnosed diabetics are over age 60, and these older diabetic adults frequently have comorbidities and functional impairments that reduce quality of life and complicate care (Gambert and Pinkstaff, 2006). Between 1990 and 2002, the prevalence of diabetes increased by 61 percent in the U.S. and it is now the seventh leading cause of death. According to CDC estimates, people with diabetes have twice the mortality risk of people of similar age without diabetes. In 2007, diabetes was the underlying cause of death for more than 71,000 Americans and a contributing cause of death for over 160,000 additional cases (Centers for Disease Control and Prevention, 2011).

Asthma

Asthma is a lung condition characterized by reversible episodes of airway obstruction that cause coughing, shortness of breath, chest tightness, and wheezing. About 7 to 10 percent of Americans have asthma, affecting about 33 million people. In 2005, an estimated 4 percent of people in the U.S. (12.2 million) had experienced at least one asthma attack in the previous year (Joubert et al., 2010). The prevalence of asthma in individuals over age 65 is estimated at 6 percent, a figure representing almost 2 million individuals, and 4.8 million older adults are expected to have asthma by 2030 (Stupka and deShazo, 2009). About 3,388 deaths each year are attributed to asthma in the U.S (Centers for Disease Control and Prevention, 2012a). Mortality rates within this group are about 10 times higher among people over age 65 than among younger adults. This statistic should be interpreted in the context of data indicating that half of older asthmatics are undiagnosed, and only 30 percent of diagnosed older patients are treated with inhaled corticosteroids (Enright et al., 1999). Further, older adults with asthma are more likely to have comorbid conditions, including heart disease, hypertension, arthritis, and stroke (Zeitz et al., 2004).

Chronic Obstructive Pulmonary Disease (COPD)

COPD is a lung disease characterized by a progressive, partially reversible limitation of airflow, typically caused by cigarette smoking. Airflow limitation is caused by two conditions, chronic bronchitis and emphysema, which occur together in most patients. Chronic bronchitis is defined clinically as persistent cough and sputum production. Emphysema is the progressive destruction of gas-exchanging surfaces of the lungs, which usually presents as chronic breathing difficulties. In 2006, more than 12.1 million American adults had COPD (American Lung Association, 2008) and an additional 24 million showed evidence of impaired lung function (Mannino et al., 2002). In the same year, COPD was a contributing factor in 39 out of every 100,000 deaths (Centers for Disease Control and Prevention, 2012b). Prevalence of COPD increases dramatically with age, with risk of a COPD diagnosis doubling every 10 years after age 40 (Mannino and Buist, 2007). Similar to both asthma and diabetes, COPD is under-diagnosed and under-treated among older adults (Mannino et al., 2002).

Hypertension

Hypertension is an abnormal elevation in force against the walls of arteries as blood pumps through the body. Hypertension affects approximately 76.4 million Americans and for many results in heart attack, HF, stroke, and kidney failure. Hypertension was listed as a primary or contributing cause of death for 347,000 Americans in 2008, underscoring the importance of this condition in mortality risk (Centers for Disease Control and Prevention, 2012c). Hypertension-related complications can be reduced and even prevented if blood pressure is well-controlled. About 64 to 70 percent of Americans age 65 to 74 have hypertension and, among those age 75 and above, the prevalence reaches 80 percent (American Heart Association, 2010). It is estimated that uncontrolled hypertension affects approximately one-third of American adults (Wolf-Maier et al., 2004), underscoring the extent of poor management of this common condition.

2.3. Costs and Burdens Associated with Chronic Diseases

The CDC estimates that chronic diseases account for 75 percent of the $1 trillion spent annually on health care in the U.S. (Centers for Disease Control and Prevention, 2009). A report from the Agency for Healthcare Research and Quality (AHRQ) found that individuals with one or more chronic conditions accounted for the overwhelming majority of total medical expenses for all conditions (among persons residing in a community setting): 96 percent for persons age 55 to 64 and 99 percent for persons age 65 and older (Agency for Healthcare Research and Quality, 2008a). Further, nearly all growth in Medicare expenditures can be traced to the 50 percent of beneficiaries with multiple chronic diseases (Thorpe and Howard, 2006). The following sections summarize costs for the five chronic conditions discussed in this chapter.

Heart Failure

In 2008, the estimated total cost (include direct and indirect costs) of heart disease in the U.S. was $190.3 billion, of which $78.2 billion, or 41 percent, were hospital costs. In this estimate, “heart disease” includes coronary heart disease, HF, some hypertensive disease, cardiac dysrhythmias, and other heart conditions (American Heart Association, 2012). By 2030, the cost of heart disease and its sequelae are expected to total $818.1 billion, $77.7 billion of which will be attributable to HF alone (Heidenreich et al., 2011).

Diabetes

The total cost of diabetes has been estimated at $174 billion per year, and experts agree that this figure likely underestimates its true costs. Direct diabetes costs (e.g., medications, hospital stays, and medical equipment) are $116 billion per year and indirect costs (e.g., lost wages and the value of lost productivity due to premature death) contribute an additional $58 billion annually (American Diabetes Association, 2008).

Total costs of diabetes in the U.S. will approach $200 billion per year by 2020 (Wyne, 2008).

Asthma

The annual cost of asthma has been estimated at $20.7 billion, with $15.6 billion and $5.1 billion in direct and indirect costs, respectively (American Lung Association, 2010). People with asthma are more likely to have comorbidities, a factor that will likely increase the complexity and costs of treating this condition (Joseph, 2006).

COPD

The total cost of COPD was estimated at $49.9 billion in 2010, a figure that includes $29.5 billion in direct health-care costs and $20.4 billion in indirect costs (National Heart Lung and Blood Institute, 2009). COPD is especially costly because of the large number of affected individuals and the extent to which this condition impairs routine function. Further, under-diagnosis and under-treatment are common and associated with increased service utilization such as emergency department visits.

Hypertension

In 2008, hypertension accounted for $50.6 billion in health-care costs, including $47.3 billion in direct medical expenses and $3.3 billion in lost productivity. This estimate includes only adults with hypertension without heart disease: costs and prevalence increase when adults with both hypertension and heart disease are taken into account (American Heart Association, 2012).

The costs and burdens of these and other common diseases of advancing age extend beyond the older adults and people with disabilities directly affected by these conditions. Spouses, adult children, friends, and neighbors are often involved in the care of chronically ill and disabled adults. Nearly 79 percent of people who need long-term care live at home or in community settings rather than in institutions, and informal caregivers play a large role in helping these individuals remain in the community. In 2007, about 39 million U.S. households were involved in caring for someone age 50 or older. The value of uncompensated services that family caregivers provide is estimated at $257 billion per year (Family Caregiver Alliance, 2004), the majority of which is allocated for care of persons with chronic conditions. Although family caregiving increases satisfaction with the level of care received by older adults and individuals with disabilities with chronic diseases, providing these services creates substantial health and social burdens on families, thereby adding to the costs associated with these conditions (National Alliance for Caregiving, 2009).

2.4. Available Chronic Disease Management Technologies and Evidence of Their Benefits

There is a wide array of technologies on the market aimed at various aspects of chronic disease management. Most of these address one or more of the fundamental issues of central importance to a successful disease management program: (1) frequent monitoring; (2) communication and care coordination; and (3) promotion of effective and sustained self-care. Examples of how these technologies can assist health-care professionals include providing serial data on physiological parameters and generating integrated patient profiles that enable monitoring of the short- and long-term effectiveness of prescribed interventions (Bowe, 2006). These technologies can also assist patients and caregivers by providing tailored educational materials and management tools to assist in monitoring and self-management (Center for Information Technology Leadership, 2007).

Most of the published research on the impact of technology on chronic disease self-management has involved studies of telehealth and telemonitoring. Accordingly, the following section provides an overview of these technologies, followed by information on other technology-enhanced solutions for chronic disease management used by older adults and people with disabilities as well as their caregivers and health-care providers.

Telehealth and Remote Patient Monitoring

Telehealth involves systems that deliver health-related services and information via telecommunication technologies and that target prevention, health promotion, and cure. Telehealth delivery can consist of two health-care professionals discussing a case over the telephone, or be as sophisticated as a videoconference between multiple providers in remote locations. Telehealth can also affect health-care delivery by connecting health-care professionals with patients in their own homes. Currently, telehealth technologies vary in the degree to which they integrate monitoring and educational functions. While some systems primarily collect information, monitor health data, and provide feedback in the form of patient instructions, others are augmented by educational functions that allow patients to receive information through electronic messages, quick tutorials, question-and-answer sessions, or instructional videos (Schermer, 2009).

Remote patient monitoring (RPM) is a type of home telehealth that enables patient monitoring as well as transfer of patient health data to a health-care provider. To capture data, these technologies use a variety of wired or wireless peripheral measurement devices such as blood pressure cuffs, scales, and pulse oximetry, and they are most often used after a hospital discharge or between routine office visits. Some technologies also permit video interaction/chat between the patient and health-care professional in real-time (e.g., the Intel HealthGuide). These systems can prompt users to enter answers to targeted questions, and then use this information for data interpretation, provision of educational materials, as well as instructions such as scheduling an office visit or going to the nearest emergency room. Similarly, these systems can transmit user-entered data, store the data in secure records systems accessible to clinicians, flag abnormal readings or responses, and alert clinicians to abnormalities via e-mail or text messages. In response to these alerts, clinicians can log into the system, review data, follow up with patients, or take other appropriate actions. Some systems have the capacity to connect patients with additional resources such as personal health or electronic medical records, targeted educational materials, interactive self-care tools, medication optimization technologies, and health-care providers. Although applications of RPM technologies are often used in the home setting, these technologies have been pilot-tested in congregate settings such as community-based senior centers (Hovey et al., 2011).

While there is some evidence to suggest that RPM may reduce hospital utilization and improve clinical outcomes for HF and diabetes patients, small sample sizes, lack of randomization, and absence of long-term follow-up data limit many of these studies. Indeed, a review of home telemonitoring studies found inconsistent effects of telemonitoring on clinical outcomes, with about half of the reviewed studies suggesting benefits and the other half showing no effect (Barlow et al., 2007).

One review of interactive IT (including telehealth) in older, chronically ill adults found that these technologies had a positive and sustained impact on outcomes and provided a complete feedback loop that included monitoring of current patient status; interpreting monitoring data in light of individualized treatment goals; adjusting the management plan as needed; presenting the patient with tailored recommendations and advice; and repeating this cycle at appropriate intervals. Systems that provided only one or a subset of these functions were less consistently effective (Agency for Healthcare Research and Quality, 2008b). Another review noted that, although the evidence supporting the clinical benefits of information communication technologies (ICTs) in managing chronic disease is limited, ICTs for heart disease provided better clinical outcomes, including reduced mortality and lower utilization of health-care services. This report also noted that systems used for improving education and social supports were generally effective in patients with chronic diseases (Garcia-Lizana and Sarria-Santamera, 2007).

The Department of Veterans Affairs (VA) provides an example of a sophisticated application of telehealth for chronic disease management. To better coordinate non-institutional care for veterans with chronic diseases, the VA has designed a program to augment standard care. Program enrollees are assigned coordinators (nurses or social workers) who assess patients' health and recommend the telehealth devices best suited to their care needs and ability to use technology. The majority of patients are over 50 and receive care for diabetes (48 percent), hypertension (40 percent), HF (25 percent), COPD (12 percent), and other conditions. This telehealth program led to reductions in bed days (25 percent), hospital admissions (19 percent), and patient satisfaction (86 percent) (Darkins et al., 2008). In addition to improved outcomes, the program also showed cost savings: telehealth patients cost $1,600 per year, compared to $13,121 among primary care patients and $77,745 among nursing home patients.

A review of home telehealth found that, compared to conventional home care or usual care, home telehealth improved access to care, patients' medical conditions, and quality of life (Canadian Agency for Drugs and Technologies in Health, 2008). With the notable exception of work from the VA, studies focusing on the economic benefits of home telehealth are often small and do not fully support conclusions regarding the economic benefit of this technology. These results are especially equivocal when it is not appropriately integrated into providers' workflow and existing incentive structures, infrastructure and training prevent the meaningful use of the data it can provide (Soran et al., 2007; Chaudhry et al., 2010).

Mobile Devices

Use of smart phones and other mobile data devices for chronic disease management is on the rise. These devices provide wireless internet connectivity over cellular phone networks in conjunction with wireless peripheral measurement devices similar to those used with RPM technologies. These systems can track behavioral information as well as physiologic data such as blood pressure and glucose, and provide tailored feedback to a mobile device in response to this information. This fast-growing sector of telehealth has become known as "mHealth." These systems also permit physicians to access and evaluate patient data using this technology platform and tap into practice guidelines to make care plan adjustments. One recent review of cell phone, voice and text message interventions noted significant improvements in medication compliance, asthma symptoms, and diabetes control (Krishna, Boren, and Balas, 2009).

Clinical Decision Support (CDS)

Health-care providers use clinical decision support (CDS) systems to generate alerts, reminders, and customized data entry forms to help interpret results, document patient health status, and prescribe the appropriate medications (Agency for Healthcare Research and Quality, 2009). CDS is described in greater detail in the Medication Management chapter of this report (Chapter 3). CDS systems are often one element of a larger health IT system that permits ongoing monitoring of patient information. In the context of chronic disease management, these systems help clinicians schedule and remind patients about follow-up visits, lab tests, diet, exercise, and medication adherence in accordance with best practice guidelines.

Evidence Supporting the Impact of Chronic Disease Management Technologies

Heart Failure

HF is an appealing target for technology-enhanced chronic disease management because the symptoms that often signal the onset of crisis are well-recognized and can be readily monitored and detected. RPM, telehealth, and telemonitoring technologies have been examined in relation to HF outcomes as well as health-care utilization among

HF patients. A recent study compared the effect of RPM to both usual care and a chronic disease management program without RPM among patients with moderate to severe HF. This study found a 60 percent reduction in hospital readmissions using RPM compared with standard care, and a 50 percent reduction compared with disease management programs without RPM (New England Healthcare Institute, 2009). The same study estimated that RPM has the potential to prevent between 460,000 and 627,000 HF-related hospital readmissions each year, with an estimated annual cost savings of $6.4 billion. Similarly, a review of chronic disease management programs that included RPM found a 21 percent reduction in hospital admission rates for HF, and a 20 percent reduction in all-cause mortality, findings strongly suggesting that RPM has measurable benefits among HF patients (Clark et al., 2007).

A meta-analysis of telehealth studies in HF patients found that, compared to standard care, those receiving telehealth had a 42 percent reduction in hospitalizations (Wade et al., 2011). Another study found that, although telehealth did not improve mortality rates, it significantly reduced health-care utilization, including emergency room and clinic visits, and unplanned hospitalizations (Dar et al., 2009). It should be noted, however, that other reviews of the impact of telehealth on HF outcomes have yielded inconclusive results (Pare et al., 2010).

An analysis of 25 studies on telemonitoring and HF showed that both structured telephone support and telemonitoring were effective in reducing hospitalization (Inglis et al., 2010). These studies showed mixed results with respect to length of stay, quality of life, and other outcomes, but most that examined cost-effectiveness suggested this technology reduced costs. The report also pointed out that some older HF patients were unable to learn how to use this technology, a finding that underscores the importance of ease of use and appropriate training.

Diabetes

Diabetes management can involve multiple activities such as adherence to a strict schedule of blood glucose monitoring, insulin injections, prescribed skin and foot care, diet, exercise and periodic eye examinations and assessments of glucose control, blood pressure, and cholesterol. This multitude of activities introduces obvious challenges to both patients and providers seeking to engage in and monitor appropriate management. RPM can be used to enhance diabetes management by facilitating information exchange between patients and physicians as well as by providing patients with feedback on their blood glucose levels and how these levels are impacted by self-management behaviors. There is evidence to suggest that, compared to usual care, diabetic patients receiving RPM and telehealth had greater improvements in glucose control, blood pressure, and cholesterol (Shea et al., 2006). Another study of the impact of mHealth intervention on diabetes management showed significant improvement in blood glucose compared to usual care, but no changes in other outcome such as depression, blood pressure, or cholesterol (Quinn et al., 2011).

Asthma and COPD

Telemonitoring of respiratory measures can assist in the early identification of deterioration in a patient's condition and symptom control. A study of patients with moderate to severe COPD showed that, compared to usual care, case managers' use of a home-based telemonitoring device for daily symptom surveillance resulted in a significant decrease in hospital admission rates and a number of exacerbations, as well as a tendency toward fewer hospital days and outpatient visits (Trappenburg et al., 2008). Although one review of this technology that focused on asthma management did not yield compelling results (Jaana, Pare, and Sicotte, 2009), another found improvement in asthma patients' lung function and symptoms (Pare et al., 2010).

Hypertension

A review of studies on the effectiveness of blood pressure telemonitoring among patients with hypertension found that a majority of studies showed improvement in both systolic and diastolic blood pressures (AbuDagga, Resnick, and Alwan, 2010). This report also noted that health-care utilization and cost outcomes were under-investigated in the current hypertension telemonitoring literature. Another review found that virtually all RPM studies involving patients with hypertension demonstrate reductions in both systolic and diastolic blood pressure (Pare et al., 2010).

2.5. Chronic Disease Management Technologies Under Development

A number of innovative chronic disease management technologies are currently under development. Among these are cloud-computing technologies (e.g., ActiveHealth Management), which involve shared use of internet-based resources, software, and information. One system would combine information from electronic medical records, claims, medication, and laboratory data with a CDS system and deliver the information to clinicians through a cloud-computing platform. With health-care data and IT resources managed in a cloud environment, these systems could facilitate coordination of patient care among provider teams in different locations, thereby enabling them to share and address patient information from several sources at a single access point. Such a system could also show how patients respond to various chronic disease management approaches and whether they are adhering to drug regimens, and they could alert physicians to missed prescriptions or potential adverse drug events. A potential advantage of this approach is that it would not require major infrastructure investments on the part of health-care providers and payers. However, cloud platforms may raise privacy and security concerns and providers may feel that they have little control over these aspects of the technology.

Nanotechnology offers new approaches to monitoring physiologic and other measures that are fundamental to effective chronic disease management. For example, researchers are incorporating microscopic optical, electronic, and biosensing devices into contact lenses to monitor glucose, cholesterol, temperature, inflammation, infection, and fatigue. These technologies integrate tiny sensors, antennae, and radios using short-range wireless communication. Health information is then transmitted to mobile devices such as cell phones, which display or e-mail information to the person wearing the lenses, potentially increasing both the quality and quantity of information they can use for self-management (Parviz, 2009).

A key challenge in diabetes management for many patients is non-compliance with self-monitoring of blood glucose, a self-management activity that requires the patient to draw a small quantity of blood with a finger prick. New sensor technologies are emerging that help address this issue by facilitating ongoing monitoring of blood glucose without finger pricks (Darcé, 2010). One device is implanted below the collarbone or in the lower abdomen during an outpatient procedure. The system measures glucose levels and transmits data wirelessly to a portable receiver outside the body where the information can be read and acted upon by the patient. Another new glucose monitoring device involves a miniature glucose sensor that can be implanted in the eye. Preliminary work suggests this device can measure glucose in manufactured tears at tear-flow rates that approximate those in the human eye, and research in humans is in the planning stages (Yan et al., 2011). New diabetes management technologies are also emerging for patients who require insulin. One example of a new insulin delivery technology involves an implanted insulin pump that is controlled in real-time by a continuous blood glucose sensor (Catargi, 2004). Another new class of biotechnologies focuses on development of an artificial pancreas that can be implanted in the body to replace the insulin secretion function of a normal pancreas (Cerco Medical, 2010).

New technologies are also in development for blood pressure management. One example involves non-invasive, wireless monitoring systems that use pulse decomposition analysis (PDA) (e.g., CareTaker). PDA tracks blood pressure by sensing pulse pressures and using complex models of these pressures along with digital signal processing and detection algorithms to compute arterial blood pressure. These devices would be controlled from and stream data to software that runs on a personal computer over a wireless communication link. Another innovative approach to hypertension management is an implantable blood pressure telemonitor that uses a surface acoustic wave oscillator to sense pressure. The blood pressure sensor would be implanted in the heart or in a major blood vessel and integrated with an antenna and receiver that could fit in the patient’s pocket (Bush, 2010). This approach will require stringent safety assessment before it becomes commercially available. Nevertheless, a key advantage of some of these new technologies is that they can collect ongoing measurements of important physiologic parameters, thereby reducing the need for patient compliance and potentially increasing data quality.

2.6. Experiences of Other Countries with Chronic Disease Management Technologies

There is little difference between chronic disease management technologies available in the U.S. and those available in other developed countries. A number of the larger chronic disease management technology initiatives have taken place in Canada and the United Kingdom (U.K.) and these have focused on promoting adoption of technology-enhanced chronic disease management programs.

In Canada, the province of British Columbia achieved significant improvements in compliance with chronic care guidelines through use of a chronic disease management toolkit, CDS tools, and incentives for providers. This initiative showed that the proportion of diabetic people who received glucose, blood pressure, and cholesterol tests in accordance with Canadian Diabetes Association management guidelines increased from 22 percent to 49 percent over three years. During this period of enhanced focus on care management, the cost of diabetes care decreased from an average of $4,400 to $3,966 per patient. This initiative involved a relatively modest investment in health IT (Organization for Economic Co-operation and Development, 2010). The government of Ontario, Canada, has arranged to design, build, implement, and manage a province-wide chronic disease management system and portal targeting diabetes, a top clinical priority for the province. As the largest system of its kind in Canada, this technology-enhanced solution aims for earlier diagnosis of diabetes, more effective treatment, as well as improved disease management. It will generate alerts to physicians to help them better manage patient care and it will also provide a diabetes registry that will be accessible by authorized clinicians (CGI, 2010).

In the U.K., the National Health Service (NHS) has facilitated adoption of telehealth by awarding a cooperative agreement with technology vendors through which NHS organizations and local authorities will be able to purchase hi-tech products and services under pre-agreed terms and conditions. The agreement covers technologies relevant to chronic disease management, including telecare, telehealth, and telecoaching, and it aims to expedite the adoption and utilization of these products and services in the marketplace. The Department of Health (DOH) is conducting a Whole System Demonstrator (WSD) program to evaluate the efficacy and cost-effectiveness of telehealth and telecare among people with diabetes, heart failure, and COPD. The study involves 6,191 patients and 238 general practitioner practices in three counties, making it the world's largest randomized controlled trial of telehealth and telecare. Preliminary results from the telehealth groups indicate a number of successes, including a 45 percent reduction in mortality, 20 percent fewer ER admissions, and a 14 percent reduction in elective admissions. These data prompted plans for an expansion of telehealth. Over the next five years, the NHS and DOH will work with businesses, suppliers, and health-care professionals to provide three million people with home-based telehealth technologies, expanding health-care access, and connecting patients directly to their doctors. A development company will be working with suppliers to produce holistic, community-wide, remote care solutions that employ business process redesign, technology development, and change management (U.K. Department of Health, 2011).

The medical home model is an especially innovative approach to extending the application of chronic disease management technologies. This model, which is organized around the primary care physician (PCP), focuses on patient-centered care and coordinates patient care supported by shared information facilitated by technology. This approach is particularly successful in Denmark, where it has contributed to a reduction in hospital visits (Davis, 2007; Commonwealth Fund, 2008). In this model, there are organized after-hours services and a nationwide health information exchange maintained by an independent nonprofit organization. Almost all (98 percent) PCPs in Denmark have paperless offices, with prescriptions, laboratory and imaging tests, specialist consult reports, and hospital discharge letters flowing through a single electronic portal accessible to patients, physicians, and home health nurses.

References

AbuDagga, A., Resnick, H., Alwan, M. (2010). Impact of blood pressure telemonitoring on hypertension outcomes: A literature review. *Telemedicine and e-Health,* 16(7), 1-9.

Agency for Healthcare Research and Quality (2008a). Statistical Brief #203: Healthcare expenses for adults with chronic conditions, 2005. Rockville, M.D.: U.S. Department of Health and Human Services. http://meps.ahrq.gov/mepsweb/data_files/publications/st203/stat203.pdf. Accessed April 2, 2012.

Agency for Healthcare Research and Quality (2008b). Barriers and drivers of health information technology use for the elderly, chronically ill, and underserved. Rockville, M.D.: U.S. Department of Health and Human Services. http://www.ahrq.gov/clinic/tp/hitbartp.htm. Accessed April 2, 2012.

Agency for Healthcare Research and Quality (2009). Innovations in using health IT for chronic disease management: Findings from the AHRQ health IT portfolio. Rockville: M.D.: U.S. Department of Health and Human Services. http://healthit.ahrq.gov/images/jan09cdmreport/cdm_issue_paper.htm. April 2, 2012.

AARP (2011). Valuing the invaluable: 2011 Update- The growing contributions and costs of family caregiving. http://assets.aarp.org/rgcenter/ppi/ltc/i51-caregiving.pdf. Accessed April 2, 2012.

American Diabetes Association. (2008). Economic Costs of Diabetes in the United States in 2007. *Diabetes Care*, 31(3), 596-615.

American Heart Association (2010). Heart disease and stroke statistics--2010 update. A report from the American Heart Association statistics committee and stroke statistics subcommittee. *Circulation*, 121, 1-170.

American Heart Association (2012). Heart disease and stroke statistics--2012 update. A report from the American Heart Association. *Circulation*, 125, e2-e220.

American Lung Association (2008). Chronic obstructive pulmonary disease. http://www.lungusa.org/assets/documents/publications/solddc-chapters/copd.pdf. Accessed April 2, 2012.

American Lung Association (2010). Trends in asthma morbidity and mortality. http://www.lungusa.org/finding-cures/our-research/trend-reports/asthma-trend-report.pdf. Accessed April 22, 2012.

Barlow, J., Singh, D., Bayer, S., Curry, R. (2007). A systematic review of the benefits of home telecare for frail elderly people and those with long-term conditions. *Journal of Telemedicine and Telecare,* 13(4), 172-179.

Bowe, T. (2006). Remote physiological monitoring (RPM): Discussion paper. http://muskie.usm.maine.edu/Publications/ihp/RPM.pdf. Accessed April 2, 2012.

Bush, S. (2010). Imperial heart implant pulses RF piezo oscillator. ElectronicsWeekly.com. http://www.electronicsweekly.com/Articles/2008/07/03/44043/imperial-heart-implant-pulses-rf-piezo-oscillator.htm. Accessed April 2, 2012.

Canadian Agency for Drugs and Technologies in Health (2008). Home Telehealth for Chronic Disease Management. http://www.cadth.ca/en/products/health-technology-assessment/publication/865. Accessed April 2, 2012.

Care Continuum Alliance (2012). Care Continuum Alliance (CCA) Definition of disease management. http://www.carecontinuum.org/dm_definition.asp. Accessed April 2, 2012.

Catargi, B. (2004). Current status and future of implantable insulin pumps for the treatment of diabetes. *Expert Review of Medical Devices*, 1(2), 181-185.

Census Bureau (2008). Projections of the population by selected age groups and sex for the U.S.: 2010 to 2050. Washington, D.C.: U.S. Census Bureau. http://www.census.gov/population/www/projections/summarytables.html. April 2, 2012.

Centers for Disease Control and Prevention (2007a). National diabetes fact sheet: General information and national estimates on diabetes in the U.S., 2007. Atlanta, G.A.: U.S. Department of Health and Human Services. http://www.cdc.gov/diabetes/pubs/pdf/ndfs_2007.pdf. Accessed April 2, 2012.

Centers for Disease Control and Prevention and The Merck Company Foundation (2007b). The state of aging and health in America 2007. Whitehouse Station, N.J.: The Merck Company Foundation. http://www.cdc.gov/Aging/pdf/saha_2007.pdf. Accessed April 2, 2012.

Centers for Disease Control and Prevention (2009). Chronic Diseases: The power to prevent, the call to control: At a glance 2009. Atlanta, G.A.: U.S. Department of Health and Human Services. http://www.cdc.gov/chronicdisease/resources/publications/aag/chronic.htm. Accessed April 2, 2012.

Centers for Disease Control and Prevention (2011). National diabetes fact sheet: national estimates and general information on diabetes and prediabetes in the United States, 2011. U.S. Department of Health and Human Services. http://www.cdc.gov/diabetes/pubs/pdf/ndfs_2011.pdf. Accessed April 12, 2012.

Centers for Disease Control and Prevention (2012a). Asthma. Atlanta, GA: U.S. Department of Health and Human Services. http://www.cdc.gov/nchs/fastats/asthma.htm. Accessed April 12, 2012.

Centers for Disease Control and Prevention (2012b). Data and statistics. Atlanta, GA: U.S. Department of Health and Human Services. http://www.cdc.gov/copd/data.htm. Accessed April 12, 2012.

Centers for Disease Control and Prevention (2012c). High blood pressure facts. Atlanta, GA: U.S. Department of Health and Human Services. http://www.cdc.gov/bloodpressure/facts.htm. Accessed April 12, 2012.

Center for Information Technology Leadership (2007). The value of information technology-enabled diabetes management. http://www.partners.org/cird/pdfs/CITL_ITDM_Report.pdf. Accessed April 2, 2012.

Cerco Medical (2010). Research and development: Bio-artificial pancreas. http://www.cercomed.com/pages/rnd_bioartificial.htm. Accessed April 2, 2012.

CGI (2010). CGI signs $46 million, six-year contract with eHealth Ontario for a diabetes registry and portal solution. http://www.cgi.com/en/CGI-Signs-46-Million-Six-Year-Contract-eHealth-Ontario-Diabetes-Registry-Portal-Solution. Accessed April 2, 2012.

Chaudhry, S., et al., "Telemonitoring in Patients with Heart Failure," *New England Journal of Medicine* 353 (2010):2301.

Clark, R.A., Inglis, S.C., McAlister, F.A., Cleland, J.G., Stewart, S. (2007). Telemonitoring or structured telephone support programmes for patients with chronic heart failure: Systematic review and meta-analysis. *British Medical Journal*, 334(7600), 942.

Commonwealth Fund (2008). Organizing the U.S. healthcare delivery system for high performance. http://www.commonwealthfund.org/Publications/Fund-Reports/2008/Aug/Organizing-the-U-S--Health-Care-Delivery-System-for-High-Performance.aspx. Accessed April 2, 2012.

Cowie, C.C., Rust, K.F., Ford, E.S., Eberhardt, M.S., Byrd-Holt, D.D., Li, C. (2009). Full accounting of diabetes and pre-diabetes in the U.S. population in 1988-1994 and 2005-2006. *Diabetes Care*, 32(2), 287-294.

Dar, O., Riley, J., Chapman, C., Dubrey, S.W., Morris, S., Rosen, S.D., Roughton, M., Cowie, M.R. (2009). A randomized trial of home telemonitoring in a typical elderly hearth failure population in North West London: Results of the Home-HF study. *European Journal of Heart Failure*, 11(3), 319-325.

Darcé, K. (2010). S.D. company hopes monitor will revolutionize diabetes care. University of California, San Diego. http://www.californiahealthline.org/articles/2010/8/2/device-aims-to-improve-selfmonitoring-for-diabetes-care.aspx. Accessed April 2, 2012.

Darkins, A., Ryan, P., Kobb, R., Foster, L., Edmonson, E., Wakefield, B., Lancaster, A.E. (2008). Care coordination/home telehealth: The systematic implementation of health informatics, home telehealth, and disease management to support the care of veteran patients with chronic conditions. *Telemedicine e-Health*, 14(10), 1118-1126.

Davis, K. (2007). Learning from high performance health systems around the globe. Senate Health, Education, Labor, and Pensions Committee Invited Testimony, Hearing on healthcare coverage and access: Challenges and opportunities. http://www.commonwealthfund.org/usr_doc/996_Davis_learning_from_high_perform_hlt_sys_around_globe_Senate_HELP_testimony_01-10-2007.pdf?section=4039. Accessed April 2, 2012.

Enright, P.L., McClelland, R.L, Newman, A.B., Gottlieb, D.J., Lebowitz, M.D. (1999). Underdiagnosis and undertreatment of asthma in the elderly. *Chest*, 116(3), 603-613.

Family Caregiver Alliance. (2004). Fact sheet: selected long term care statistics. http://www.caregiver.org/caregiver/jsp/content_node.jsp?nodeid=440. Accessed May 24, 2012.

Friedewald, V. Pion, R. (2001). Returning home. *Health Management Technology*, 22(9), 22-24.

Gambert, S., Pinkstaff, S. (2006). Emerging epidemic: Diabetes in older adults: Demography, economic impact, and pathophysiology. *Diabetes Spectrum*, 19(4), 221-228.

Garcia-Lizana, F., Sarria-Santamera, A. (2007). New technologies for chronic disease management and control: A systematic review. *Journal of Telemedicine and Telecare*, 13(2), 62-68.

Heidenreich, P.A., Trogdon, J.G., Khavjou, O.A., Butler, J., Dracup, K., Ezekowitz, M.D., Finkelstein, E.A., Hong, Y., Johnston, S.C., Khera, A., Lloyd-Jones, D.M., Nelson, S.,A., Nichol, G., Orenstein, D., Wilson, P.W., Woo, Y.J. (2011). Forecasting the future of cardiovascular disease in the U.S.: A policy statement from the American Heart Association. *Circulation*, 123(8), 933-944.

Hovey, L., Kaylor, M.B., Alwan, M., Resnick, H.E. (2011). Community-based telemonitoring for hypertension management: Practical challenges and potential solutions. *Journal of Telemedicine and E-Health*, 17(8), 645-651.

Inglis, S.C., Clark, R.A., McAlister, F.A., Ball, J., Lewinter, C., Cullington, D. (2010). Structured telephone support or telemonitoring programmes for patients with chronic heart failure. *Cochrane Database of Systematic Reviews*, 4(8), CD007228.

Jaana, M., Pare, G., Sicotte, C. (2009). Home telemonitoring for respiratory conditions: A systematic review. *The American Journal of Managed Care*, 15(5), 313-320.

Joseph, A. M. (2006). Care coordination and telehealth technology in promoting self-management among chronically ill patients. *Telemedicine Journal and E-Health*, 12(2), 156-159.

Joubert, A., Kidd-Taylor, A., Christopher, G., Nanda, J., Warren, R., Lindong, I. (2010). Complementary and alternative medical practice: Self-care preferred vs. practitioner-based care among patients with asthma. *Journal of the National Medical Association*, 102(7), 562-569.

Krishna, S., Boren, S.A., Balas, E.A. (2009). Healthcare via cell phones: A systematic review. *Telemedicine and e-Health*, 15(3), 231-240.

Krumholz, H., Chen, Y., Wang, Y., Vaccarino, V., Radford, M., Horwitz, R. (2000). Predictors of readmission among elderly survivors of admission with heart failure. *American Heart Journal*, 139(1 Pt. 1), 72-77.

Liu, L. (2010). Changes in cardiovascular hospitalization and comorbidity of heart failure in the United States: Findings from the national hospital discharge surveys 1980-2006. *International Journal of Cardiology*, 149(1), 39-45.

Lloyd-Jones, D., Adams, R.J., Brown, T.M, et al. (2010). Heart Disease and Stroke Statistics--2010 Update. A Report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Circulation, 121, e1-e170.

Mannino, D.M., Buist, A.S. (2007). Global burden of COPD: Risk factors, prevalence, and future trends. *Lancet*, 370(9589), 765-773.

Mannino, D.M., Homa, D.M., Akinbami, L.J., Ford, E.S., Redd, S.C. (2002). Chronic obstructive pulmonary disease surveillance- United States, 1971-2000. *Morbidity and Mortality Weekly Report (MMWR) Surveillance Summaries*, 51(6), 1-16.

McMahon, G.T., Gomes, H.E., Hickson Hohne, S., Hu, T.M., Levine, B.A., Conlin, P.R. (2005). Web-based care management in patients with poorly controlled diabetes. *Diabetes Care*, 28(7), 1624-1629.

Moser, D., Mann, D. (2002). Improving outcomes in heart failure: It's not unusual beyond usual care. *Circulation*, 105(24), 2861-2866.

National Alliance for Caregiving and AARP (2009). Caregiving in the U.S. 2009. http://www.caregiving.org/data/Caregiving_in_the_US_2009_full_report.pdf. Accessed April 2, 2012.

National Heart Lung and Blood Institute (2009). Morbidity and mortality: 2009 Chartbook on cardiovascular, lung and blood diseases. Bethesda, M.D.: Department of Health and Human Services. http://www.nhlbi.nih.gov/resources/docs/cht-book.htm. Accessed April 2, 2012.

New England Healthcare Institute (2009). Remote physiological monitoring: Research update. http://www.nehi.net/publications/36/remote_physiological_monitoring_research_update. Accessed April 2, 2012.

Organization for Economic Cooperation and Development (2010). Improving Health Sector Efficiency: The Role of Information and Communication Technologies, Chapter 1: Generating value from health ICTs. http://www.oecd.org/dataoecd/3/47/45428392.pdf. Accessed April 2, 2012.

Pare, G., Moqadem, K., Pineau, G., St-Hilaire, C. (2010). Clinical effects of home telemonitoring in the context of diabetes, asthma, heart failure and hypertension: a systematic review. *Journal of Medical Internet Research*, 12(2), e21.

Parviz, B.A. (2009). Augmented reality in a contact lens. Institute of Electrical and Electronics Engineers Spectrum. http://spectrum.ieee.org/biomedical/bionics/augmented-reality-in-a-contact-lens/0. Accessed April 2, 2012.

Perrin, E.C., Newacheck, P., Pless, I.B., Drotar, D., Gortmaker, S.L., Leventhal, J. (1993). Issues involved in the definition and classification of chronic health conditions. *Pediatrics*, 91(4), 787-793.

Quinn, C.C., Shardell, M.D., Terrin, M.L., Barr, E.A., Ballow, S.H., Gruber-Baldini, A.L. (2011). Cluster-randomized trial of a mobile phone personalized behavioral intervention for blood glucose control. *Diabetes Care*, 34(9), 1934-1942

Roger, V., Weston, S., Redfield, M., Hellermann-Homan, J., Killian, J., Yawn, B. (2004). Trends in heart failure incidence and survival in a community-based population. *Journal of the American Medical Association*, 292(3), 344-350.

Schermer, M. (2009). Telecare and self-management: Opportunity to change the paradigm? *Journal of Medical Ethics*, 35(11), 688-691.

Shea, S., Weinstock, R.S., Starren, J., Teresi, J., Palmas, W., Field, L. (2006). A randomized trial comparing telemedicine case management with usual care in older, ethnically diverse, medically underserved patients with diabetes mellitus. *Journal of the American Medical Informatics Association*, 13(1), 40-51.

Soran, O., et al., "Randomized Clinical Trial of the Clinical Effects of Enhanced Heart Failure Monitoring Using a Computer-Based Telephonic Monitoring System in Older Minorities and Women," *Journal of Cardiac Failure* 13, no. 9 (2007): 793.

Stretcher, V. Rosenstock, I.M. (1997). The health belief model. In K. Glanz, F.M. Lewis, B.K. Rimer. Health behavior and health education: Theory, research and practice. San Francisco: Jossey-Bass.

Stupka, E., deShazo, R. (2009). Asthma in seniors: Part 1. Evidence for underdiagnosis, undertreatment, and increasing morbidity and mortality. *The American Journal of Medicine*, 122(1), 6-11.

Thorpe, K.E., Howard, D.H.. The rise in spending among Medicare beneficiaries: the role of chronic disease prevalence and changes in treatment intensity. *Health Affairs*, 25(5), 378-88.

Trappenburg, J.C., Niesink, A., de Weert-van Oene, G.H., van der Zeijden, H., van Snippenburg, R., Peters, A., Lammers, J.W., Schrijvers, A.J. (2008). Effects of telemonitoring in patients with chronic obstructive pulmonary disease. *Journal of Telemedicine E-Health*, 14(2), 138-146.

Verbrugge, L.M., Jette, A.M. (1994). The disablement process. *Social Science & Medicine*, 38(1), 1-14.

United Kingdom Department of Health (2011). Whole system demonstrator program: Headline findings--December 2011. http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_131689.pdf. Accessed April 2, 2012.

Wade, M.J., Desai, A.S., Spettell, C.M., Snyder, A.D., McGowen-Stackewicz, ,V., Kummer, P.J., Maccoy, M.C., Krakauer, R.S. (2011). Telemontiroing with case management for seniors with heart failure. *American Journal of Managed Care*, 17(3), e71-79.

Wolf-Maier, K., Cooper, R.S., Kramer, H., Banegas, J.R., Giampaoli, S., Joffres, M.R. (2004). Hypertension treatment and control in five European countries, Canada, and the United States. *Hypertension*, 43(1), 10-17.

Wyne, K. (2008). Information technology for the treatment of diabetes: Improving outcomes and controlling costs. *Journal of Managed Care Pharmacy*, 14(Suppl. 2), S12-17.

Yan, Q., Peng, B., Su, G., Cohan, B.E., Major, T.C., Meyerhoff, M.E. (2011). Measurement of tear glucose levels with amperometric glucose biosensor/capillary tube configuration. *Analytical Chemistry*, 83(21), 8341-8346.

Zeitz, H., Lutfiyya, M., Kappleman, J., McCullough, J. (2004). Co-morbidities in adults with asthma: Cross-sectional analyses using 2001 behavioral risk factor surveillance survey (BRFSS) data. *The Journal of Allergy and Clinical Immunology*, 113(Suppl. 2), S81.

CHAPTER 3: MEDICATION MANAGEMENT

3.1. Definition of Medication Management

Medication management is a process that aims to facilitate safe and effective use of medications. This process involves several phases: (1) prescribing in the outpatient setting or ordering in the hospital and long-term care settings; (2) order communication, including transmission and verification; and (3) dispensing and administration.

Medication prescribing or ordering involves selecting a medication from the pharmacy benefit list and obtaining appropriate dispensing authorization. Order communication involves the clinician transmitting a prescription or order, and the pharmacist's subsequent review and approval of this transmission. Medication dispensing and administration involve provision of a supply of medication to an individual for whom it is ordered, giving the prescribed dosage to the patient, and documenting the medication order (Agency for Healthcare Research and Quality, 2010).

Each phase of medication management can introduce problems that can be addressed by existing and emerging technologies. Medication errors involve provision of the wrong medication or dosage, and can occur at the prescribing, dispensing, and administration phases of medication management. Adverse drug events (ADEs) are injuries (physical or mental harm, or loss of function) that result from medication errors and can occur in any phase of the medication management process. Medication errors that can lead to ADEs stem from issues such as unfavorable drug-drug interactions and drug allergies (National Academy of Sciences, 2007).

Although ADEs are closely connected with provider behavior, patients also have a critical role in medication management. Medication adherence is defined as the extent to which patients take medications as prescribed by their health-care providers (Osterberg and Blaschke, 2005). While medication non-adherence can result from a choice on the part of the patient not to comply with the advice of their health-care providers, it is also caused by patients' inability to comply with this advice. Whether by choice or not, medication non-adherence is a challenging issue among older adults and people with disabilities. This important aspect of medication management is related to the dispensing and administration phases, and is most relevant to those in outpatient settings.

Older adults and persons with disabilities are generally more likely to suffer from multiple chronic conditions, to have multiple health-care providers, to experience decreased cognition, and to transition among multiple care settings. As a result, there are increased challenges associated with adequate medication management in these populations. For example, it is often the case that, as the number of chronic conditions or the severity of disability increases, so too does the number of prescribed medications, each with its own medication regimen. Polypharmacy (concurrent use of multiple medications for treatment of one or more conditions) increases the risk of both ADEs and non-adherence, especially among those with cognitive impairment who often experience particular difficulties remembering to take their medications as prescribed (Murray et al., 2004).

Compounding the issues of comorbidity, polypharmacy, and cognitive impairment is the fact that older adults and those with disabilities often see multiple health-care providers, each of whom may prescribe medications independently of other providers. Further, if patients use multiple pharmacies, individual providers and pharmacies are unlikely to have comprehensive, up-to-date information about current medications or medication histories. This fragmentation of medication information can increase risk of medication errors and ADEs (Schafer, 2001).

Finally, older adults and those with disabilities may use medications in multiple settings, including their own homes, hospitals, assisted-living facilities, and nursing homes, and they may experience frequent transitions across these settings. Medication management problems can occur in all care settings and in all phases of the medication management process. For example, medication errors and ADEs can occur with prescribing/ordering medications in nursing homes, hospitals, home health-care settings, and assisted-living facilities. The patchwork of settings in which older adults and people with disabilities commonly receive care can introduce additional challenges for medication management. When patients transition across settings, critical health information, including information about medications, drug allergies, and co-morbidities is not always effectively communicated, thereby increasing the risk of medication errors and ADEs (Kripalani et al., 2007).

3.2. Prevalence of Problems Related to Medication Management

Although the Institute of Medicine has reported that medication errors harm at least 1.5 million people annually, these errors are difficult to estimate accurately and vary by care setting, patient population, and provider (Institute of Medicine, 2006). Moreover, because there are no standard mechanisms or protocols concerning medication errors, not all errors are detected and not all detected errors are reported (Hughes, 2008). Despite these challenges, one study found that medication errors occurred at about the same rates during the order, transcription/dispensing, and administration phases of the medication management process (Poon et al., 2010), while other work suggests that most errors involve ordering and prescribing (Bates et al., 1995; Gurwitz et al., 2003).

Most information on medication errors in nursing homes relates to medication administration because dispensing is usually outsourced to long-term care pharmacies. Medication errors in this setting have been estimated to occur once in every five doses (Barker et al., 2002). Since medication administration error rates are higher in nursing homes than in hospitals, on a per-day basis, nursing-home residents are more likely than hospital patients to experience medication errors (National Academy of Sciences, 2007).

ADEs are the sixth leading cause of mortality among hospital patients, with 400,000 preventable ADEs estimated to occur in hospitals each year (Taylor and Tamblyn, 2004; Institute of Medicine, 2006). The notion of preventable ADE-related mortality is not limited to the hospital setting: 800,000 preventable ADEs are estimated to occur each year in nursing homes, and 530,000 among Medicare beneficiaries in outpatient clinics (Institute of Medicine, 2006). Approximately one in seven nursing-home residents with an ADE requires hospitalization, underscoring the connection between medication errors and care transitions among older adults (Harjivan and Lyles, 2002). Medication errors and ADEs can also occur in home health-care settings, especially as the number of medications increases. One study surveyed more than 6,700 people and found that problems with medication occurred in approximately one third of those surveyed (Meredith et al., 2001).

Quantifying medication adherence among older adults and people with disabilities is hampered by challenges associated with lack of standard definitions and approaches to detection and reporting. Currently, self-reporting is the most common approach to ascertaining medication adherence, although this method is often unreliable (Gellad, Grenard, and McGlynn, 2009). Nonetheless, a survey by the National Community Pharmacists Association found that approximately 75 percent of American consumers report not taking their medicine as prescribed (National Council on Patient Information and Education, 2007). It is reasonable to speculate that, as age and the number of medical conditions and medications increase, and as cognitive function decreases, the accuracy of self-reported medication adherence information may decrease. Indeed, one meta-analysis reported medication adherence rates among adults age 65 and older ranging from 26 to 59 percent (Conn et al., 2009). Another report found that 29 percent of Medicare beneficiaries with disabilities skipped medications, reduced dosages, or failed to fill prescriptions due to cost (American Psychological Association, 2011). Lack of patient adherence contributes to medication errors, with one study finding that 21 percent of errors in older adults were related to medication non-adherence (Gurwitz et al., 2003).

3.3. Cost and Burdens Associated with Inadequate Medication Management

Medication errors, ADEs and medication non-adherence have a cross-cutting impact on providers, patients, and caregivers. Acute and long-term care providers bear a significant proportion of the costs and burdens associated with these problems because of the frequent transitions that older adults and persons with disabilities make between these settings in the course of care. Examples of costs that may result from medication management problems include the treatment of unfavorable health outcomes, preventable hospital and nursing home admissions, as well as the formal and informal services and supports that are necessary because of these problems.

The costs associated with medication management problems are significant and vary by payer and cost-calculation method. According to one assessment, the U.S. spends approximately the same amount on treating medication-related problems as it does on the prescription medications themselves (Schlosberg, 2008). In 2000, the estimated cost of medication-related morbidity and mortality in the ambulatory care setting exceeded $177.4 billion; hospitalizations accounted for 70 percent ($121.5 billion) of these costs and long-term care accounted for 18 percent ($32.8 billion). Physician ($13.8 billion) and emergency department visits ($5.8 billion) accounted for substantial, but smaller portions of these costs (Ernst and Grizzle, 2001). Problems with medication management also increase nursing home resource utilization, including physician visits, use of allied health professional services, laboratory and monitoring services, as well as the treatment of new medical problems resulting from medication-management issues (including the costs of the medications needed to treat these new problems) (Bootman, Harrison, and Cox, 1997). In addition, it has been shown that serious injuries such as falls and hip fractures are associated with medication problems such as medication side effects (e.g., drowsiness) and drug-drug interactions (American Society of Consultant Pharmacists, 2010).

Apart from costs incurred as a result of medication errors originating with providers, medication non-adherence on the part of patients results in additional costs and excess hospitalization. One study reported that non-adherence, along with suboptimal prescribing, drug administration, and diagnosis result in as much as $290 billion annually in avoidable medical costs, a figure equivalent to 13 percent of total health-care expenditures (New England Healthcare Institute, 2009). Another study found that poor medication adherence may account for up to 10 percent of hospital admissions (Conn et al., 2009). It has been shown that improved patient self-management and adherence is associated with a reduction in the number of hospitalized patients, hospital days, and outpatient visits, with a cost-to-savings ratio of approximately 1 in10 in some cases (National Council on Patient Information and Education, 2007). In addition to increased cost to the health-care system, medication non-adherence results in less favorable disease trajectories and added patient burden. Patients who do not adhere to their medication regimens are nearly three times less likely to have favorable health outcomes than are those who follow provider instructions (Conn et al., 2009).

3.4. Available Medication Management Technologies and Evidence of Their Benefits

Technology solutions, including health information technologies like electronic health records (EHRs) with electronic prescribing (e-prescribing) and computerized physician order entry (CPOE) functionality as well as clinical decision support (CDS) systems, have the potential to reduce medication errors and ADEs associated with both prescribing/ordering medications and communication of medication orders. Electronic medication administration records (eMAR), bar-coded point-of-care systems, and remote pharmacy systems can reduce medication errors during medication administration in nursing homes, assisted living, and hospital settings. Further, software-based screening protocols and medication reviews by pharmacists can improve appropriate use and reduce potential for errors (Agency for Healthcare Research and Quality. 2010). Medication reminder, dispensing and monitoring systems can improve medication management in the home, thereby reducing the non-adherence that can ultimately lead to ADEs in this setting.

An EHR has been defined as a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting (Healthcare Information and Management Systems Society, 2011). A patient's medications, allergies, and problems are included in this information. E-prescribing is computer-based support for writing and transmitting prescriptions between a prescriber and a dispenser (e.g., a pharmacy); CPOE is a computer-based system that automates the process by which a clinician enters orders, including medication orders, and transmits them to laboratories, nursing homes, and pharmacies. A CDS system has interactive software designed to assist physicians and other health-care professionals with decision-making tasks such as determining patient diagnoses and issuing warnings. CDS systems link health observations with health knowledge in ways that help clinicians provide improved care. Together, these systems can reduce medication errors and ADEs associated with the prescribing/ordering and communication phases of medication management.

E-prescribing and CPOE functionalities within an EHR can improve prescribing and ordering by catching errors at the point of care and reducing communication errors due to illegible handwritten prescriptions as well as miscommunication between physicians and pharmacists (Center for Improving Medication Management, 2008). These systems give providers access to patients' health records, including existing medications, medication history, drug allergies, and other information. The increased access to patient information offered by these systems not only results in safer prescribing practices, it can also facilitate eligibility and formulary checks. E-prescribing and CPOE become increasingly beneficial when used in combination with advanced features such as CDS that provide real-time feedback to help prevent medication-related problems. This type of support may involve patient-specific alerts that include information about allergies, drug interactions, medication history, pharmacy eligibility, drug coverage, formulary composition, other benefits, and any necessary dosage adjustments (Bell and Friedman, 2005).

CPOE and CDS vary in both complexity and capability. A review of CDS implementation studies showed that 68 percent of studies indicated improvement in clinical practice, including drug dosing and preventive care. The review concluded that the most important features of CDS systems were automatic provision of decision support as part of clinician workflow, decision support at the time and location of decision-making, providing a recommendation, and using a computer to generate decision support. Nearly all systems that had these four features (94 percent) improved clinical practice, compared to systems (46 percent) that had none of these features (Kawamoto et al., 2005).

Published research has examined how e-prescribing systems operating independently and CPOEs that interface with CDS affect medication errors and ADEs. These reports, which focus primarily on academic hospitals, suggest that CPOEs and CDS systems reduce medication errors (Agency for Healthcare Research and Quality, 2001). A recent review of the literature on e-prescribing assessed medication errors and ADEs in the outpatient, inpatient, and intensive care settings, and found a significant risk reduction in all three settings. However, the magnitude of risk reduction varied by care setting, study design, sample size, and duration of follow-up. This review also showed that custom-designed systems developed within an organization showed greater declines in medication errors than commercial systems, and that systems with advanced CDS showed greater benefit than did those with limited or no CDS. Despite these findings, the authors cautioned that more randomized controlled trials were needed to solidify the evidence base supporting the benefits of these technologies (Ammenwerth et al., 2008).

Computerized prescribing alerts can reduce use of potentially inappropriate medications that could lead to ADEs. A five-year study of computerized decision support tools found that drug-specific alerts in a community practice setting reduced the use of potentially inappropriate medications in patients age 65 and older (Simon et al., 2006). Another study found that CPOE systems have been shown to reduce 55 percent of serious medication errors, and 17 percent of adverse drug reactions, leading to reductions of $500,000 in pharmacy charges and $26 per emergency visit (First Consulting Group, 2004).

One of the few studies conducted in long-term care settings involved evaluation of a clinical event monitor to detect ADEs in nursing homes and suggested that ADEs can be detected with a high degree of accuracy in this setting (Handler et al., 2008). Another study demonstrated that computerized CDS for physicians improved the quality of prescribing for nursing-home residents with renal insufficiency (Field et al., 2009). As for potential cost savings, another study, which focused on long-term care facilities, found that CDS for medication ordering reduced costs by $1,391.43, a 7.6% net reduction (Subramanian et al., 2012).

Even though these systems may require a significant up-front investment depending on individual providers' characteristics and needs, it has been reported that substantial savings can be realized from improved communication, charge capture, and immediate response to laboratory results. For example, one hospital in Massachusetts spent nearly $12 million to develop, implement, and operate a CPOE system between 1993 and 2002. This facility achieved a budget savings of nearly $10 million over the same time period (Kaushal et al., 2006).

Health-care professionals and clinicians use eMAR systems to manage workflow by documenting administration times for electronically ordered medications. These systems record patient medication, dose, and timing information, as well as special administration instructions. Nurses use eMAR systems to document medication administration as well as reasons for non-administration. The systems generate alerts to prevent the wrong medication from being administered, prevent medication from being administered to the wrong person, and provide alerts when medications are overdue. Finally, they store medication-related activities, thereby providing a medication record for each patient (Hillestad et al., 2005).

Bar-coded medication administration (BCMA) combines eMAR with bar-coding equipment and software to ensure accurate medication administration and reduce medication errors at the point of care. Similar to the CPOE systems, the level of initial investment for BCMA can be significant. For instance, the five-year cost for a custom-designed BCMA system at one hospital was $2.24 million, including planning, development, and rollout ($1.31 million), as well as $342,000 in annual operating costs. Nevertheless, this system surpassed the break-even point and generated positive financial returns on investment within 4.5 years of full implementation (Maviglia et al., 2007).

Evidence supporting the benefit of bar-coding and eMAR in hospitals is limited, with few rigorous studies examining health outcomes (Oren, Shaffer, and Guglielmo, 2003). Similarly, there have been few controlled trials of bar-coding and eMAR in nursing homes (National Academy of Sciences, 2007). Among published studies addressing outcomes associated with bar-coding and/or eMAR systems, a hospital-based study found that implementation of bar-coded medication verification technology embedded in an eMAR was associated with a 41 percent reduction in incorrect dosing and a 51 percent reduction in potential ADEs associated with those errors. This report also showed a 27 percent decrease in errors associated with the timing of medication administration. Based on these findings, it has been estimated that BCMA could prevent approximately 95,000 potential ADEs each year at the point of medication administration as well as an additional 50,000 potential ADEs related to transcription errors (Poon et al., 2010).

Another study reported a 71 percent decrease in medication errors when nurses used bar-codes in a point-of-care information system. However, in this study, the bar-coding device was frequently avoided for several reasons, including lack of coordination among nursing staff and physicians, and increased prioritization of monitored activities during busy periods (Clinical Update, 2009). Thus, although there is some evidence to suggest that these technologies may reduce medication errors, important issues related to training and workflow may also need to be addressed in order to realize the full potential of these technologies. No peer-reviewed studies assessing the efficacy of bar-coding and eMAR in nursing-home settings have been identified.

Telepharmacy facilitates access to medications and drug education for people who live in rural areas and those without easy access to traditional pharmacy services. Telepharmacy capitalizes on electronic information and telecommunications (telephone, fax machine, computer, internet, and video) to provide long-distance pharmacy services and support (Kimber and Peterson, 2006). It often involves a registered pharmacist technician delivering medications to customers after a prescription has been processed and verified by a pharmacist working from a remote or central pharmacy. Pharmacists with access to EHRs can check prescriptions for dosing, allergies, duplication, and drug interactions.

Electronic dispensing of medications in rural hospitals facilitates administration of appropriate dosages and timing of medications (Sherman, 2007). In this setting, telepharmacy can utilize automatic dispensing devices (ADD) that release prepackaged medications authorized by the pharmacist. Pharmacists can monitor the verification process, oversee restocking of the ADD, and use a videoconferencing link to counsel patients about their medications (Peterson and Anderson, 2002). Few studies have evaluated telepharmacy, and most published reports on this topic are pilot demonstrations that describe telepharmacy services and quantify the number of prescription consultations and costs. However, there has been some suggestion that telepharmacy offers promise for improving medication management. A survey of state rural health offices found reductions in hospital medication error rates following implementation of telepharmacy (Casey et al., 2010).

Software-aided medication review protocols used by home health agencies also facilitate collaboration with pharmacists and physicians to reduce the risk of medication errors. Using clinical information (medication use, vital signs, and other clinical indicators) collected and entered into a risk-assessment software system, users are alerted to potential medication problems determined by preset criteria. According to protocol, nurses and care managers consult with pharmacists to verify the accuracy and appropriateness of the patient's medication list and to identify potential problems that warrant reevaluation by a physician (Meredith et al., 2002).

Medication reminders, medication dispensers, and devices that combine informing, reminding, and dispensing functions are patient-focused technologies that aim to improve medication adherence. These devices are most often used among older adults and people with disabilities who live in the community as well as those in service-enriched congregate settings such as assisted-living facilities. The devices can be stand-alone or integrated into larger systems. Stand-alone technologies can provide single or multiple functions and they may also have advanced functions, including monitoring and data transmission. A single function medication dispensing system is easiest to use and least expensive, but has limited functionality by design. Multi-function systems seek to enhance medication adherence using two or more functions. Advanced technologies address one or more medication adherence elements, such as medication ingestion, metabolism, and adjustment, but are more complicated to use. Recently, medication dispensers and reminders have been integrated with health-management capabilities, such as monitoring of overall health and storage of health information. These devices may offer broader self-management opportunities for older adults and people with disabilities (Center for Technology and Aging, 2009).

Medication reminders are devices that prompt patients to take their medications using audible or visual cues or both. The complexity of these devices ranges from wrist-watch alarms that generate alerts at various times to programmable computer software that informs users when it is time to take their medications (Fuson, 2010). Because of their portability, some medication reminder devices can be incorporated into a person's daily routine with relative ease. Some devices combine a reminder technology with an automated dispenser that releases medication at specific times or intervals specified by the user (Wakefield et al., 2008). While some of these dispense only one medication, others have the capacity to dispense multiple medications and/or handle varying schedules. Medication dispensers often lack portability and require a standard electric outlet for reliable functioning. Nonetheless, they are appealing to both older adults and people with disabilities because these groups frequently have difficulty opening medication bottles, and handling and sorting small pills. These dispensers reduce the frequency with which patients need to handle medication containers, ultimately reducing difficulties associated with gaining access to the medication itself (Law et al., 2008).

The most advanced consumer-targeted technologies are devices that combine medication reminding, dispensing, and monitoring. These systems remind the user to take the medication, dispense the medication, and facilitate monitoring of when and in what quantities the medication was taken. For example, some devices ask the user to log the date and time when the medication was taken while others collect and store this information automatically. Some of these devices can also report this information to the clinician and/or caregivers using internet, telephone, or text messaging. Transmission of this information allows caregivers to monitor how well patients are adhering to their medication regimens and take action when problems occur. Medication reminder and dispenser systems can cost up to $1,000 and the caregiver notification function can cost an additional $10 to $50 per month (Wakefield et al., 2008).

Although there are only a limited number of rigorous studies evaluating medication reminder, dispenser, and monitoring devices, there is some evidence that they improve medication adherence. One study randomized 139 patients into three groups: a control group that did not receive any alerts/reminders, an intervention group that used medication bottles that remind patients to take their medication through audio and visual alerts and generate missed-dose reminder telephone calls, and an intervention-plus group that received the alerts and reminders as well as a financial incentive. After six months in the program, a preliminary analysis of this ongoing randomized trial found increased medication adherence among those receiving alerts/reminders, but no additional benefit associated with the financial incentive. Interim results showed 98 percent medication adherence among the intervention group, 99 percent adherence among the intervention-plus group, and 71 percent adherence for those who did not use the reminder-generating bottles (Center for Connected Health, 2010). Another study investigated the effects of three medication management approaches on adherence and resource utilization in older adults: a pillbox, a voice-reminder medication dispenser, and usual self-administration. Patients using the medication dispenser were significantly more adherent than were those using a pillbox and those who self-administered their medications. Moreover, the group that self-administered its medications had more physician office visits and hospitalizations (Winland-Brown and Valiente, 2000). A third study comparing automated medication dispensers to pillboxes in patients age 60 and older showed lower rates of hospitalization and emergency room visits among those using the medication dispenser (Buckwalter et al., 2004).

3.5. Medication Management Technologies Under Development

Advances in medication management technology focus on provision of more sophisticated functions that aim to enhance both patient adherence and safety. These include advanced reminding and/or dispensing functions; advanced searches of databases for potential ADEs; provision of "context-based" reminders in addition to, or in place of, traditional "time-based" reminders, and ascertainment and monitoring of medication ingestion.

One aspect of evolving medication management technology involves development of new approaches to the delivery of reminders. An example of one such technology is a device that can readjust the dosing schedule when patients are late in taking their medications. A potential advantage of this feature is that the added flexibility provided by the dispensing system will help the user remain adherent by offering an adjusted dosing schedule as an alternative to a skipped dose (Tsai et al., 2006). Other innovations involve moving away from time-based reminders and toward context-based reminders (Lundell et al., 2007). Context-based reminders are tailored in that they "learn" a patient's routine, and incorporate information from these patterns so reminders can be delivered in a manner that considers and capitalizes on the interplay of these patterns. Some context-based reminding systems identify an ideal time and place for the user to take their medication and construct activity-based "rules" that ultimately result in the user receiving a customized prompt to take the medications. Although this approach may provide some advantages over existing reminder strategies, one limitation of activity-based reminding systems is the challenge presented by situations in which the user is performing more than one activity simultaneously (Tang et al., 2010).

Another context-based approach seeks to maximize adherence by providing algorithm-based reminders when they are likely to result in the highest degree of medication adherence. These systems may improve medication adherence by reducing non-adherence associated with a reminder that is received at an inappropriate time. A preliminary evaluation of older adults with memory impairment who used such a smart medication system found 90 percent adherence among those who received context-aware prompting, 76 percent adherence among those who received routine time-based prompting, and 45 percent adherence among those who had no prompting (Tang et al., 2010).

Other advances in medication management technology focus on avoidance of ADEs. New devices contain information about the user's medications, including types of food that should be avoided when taking certain medications, and they can alert patients about potential drug-drug or drug-food interactions. Further, they can plan a medication schedule that avoids these unfavorable interactions and can adjust the dosing schedule when a dose is missed. The functionality addressing prevention of ADEs that is offered by these devices may provide meaningful advantages over current technologies that focus primarily or solely on adherence (Wang et al., 2009).

Current medication monitoring technologies that compile "adherence" data rely on medication dispensing data as a proxy for ingestion and are not capable of verifying whether the dispensed medication was actually ingested by the patient. Several systems in development stages incorporate such capabilities in order to address this shortcoming. In this general approach, a patient takes their prescribed medication, into which a microchip is embedded. The chip itself is not a pharmaceutical agent; it is an additional component that uses the prescription as a delivery device for entry into the body. The chip is activated upon ingestion of the medication and leaves the body through routine bowel movements. During the digestion process, the chip transmits information from inside the body to a data recording and transmission device worn by the user and relay the information to a health-care professional who may advise patients to adjust dosages or change medications. They can also alert caregivers if transmitted data are suggestive of low adherence (Chorost, 2008). One pharmaceutical company is planning to seek regulatory approval for the addition of this "smart pill" technology to existing drugs (Reuters, 2010). A related technology uses magnetic tracers that are embedded in pills in conjunction with a detection and transmission device worn around the neck. This approach is relatively unobtrusive due to its small size and weight (Huo and Ghovanloo, 2007). For adherence tracking, data that reflect actual ingestion of medication offer obvious advantages over data that only reflect dispensing of medication. However, one issue that smart pill technologies will need to address is how to protect patient health information when it is transmitted wirelessly from inside the body to another location such as a smart phone or health-care provider (Reuters, 2010).

Another class of evolving medication management technology involves mechanisms that detect physiologic changes in patients' bodies after they take their medications. An example of this approach uses fluorescent dye that is added to the medication and then traced as it enters the bloodstream. Concerns have been raised about the limited understanding of the long-term impact of introducing these dyes into the body in an effort to track medication adherence (Huo and Ghovanloo, 2007). Nonetheless, novel approaches to measurement of medication adherence that focus on the post-dispensing period continue to be developed and tested in an effort to generate accurate data on this aspect of medication management.

Home robots are another innovative approach to medication management. These technologies aim to improve adherence and take targeted action when adherence is not achieved. One prototype features a medication dispenser combined with a monitoring technology that detects removal and return of the dispenser. The robot can deliver data to clinical personnel when non-adherence is detected, thereby facilitating clinical intervention (Takacs and Hanak, 2008). Notably, the robot has digital "faces" that provide visual feedback to the patient concerning their medication adherence, a particularly useful feature for older adults and others with cognitive impairment.

3.6. Experiences of Other Countries with Medication Management Technologies

A number of developed countries have medication management technologies that are similar to those used in the U.S. However, there are several unique medication management technology projects currently underway in the European Union (EU) that may contribute to the development of new technologies or improvements in existing technologies by increasing our understanding of various problems associated with medication management. For instance, the Patient Safety through Intelligent Procedures in Medication (PSIPM) project seeks to improve knowledge of ADEs through analysis and mining of hospital data repositories. The project seeks to assess risks for and probable causes of ADEs using data such as diagnoses, medical histories, and lab results (Patient Safety through Intelligent Procedures in Medication, 2010). The Early Detection of ADEs by Integrative Mining of Clinical Records and Biomedical Knowledge (ALERT Project) is similar to the PSIPM and aims to better detect ADEs as well as determine frequencies of disease occurrence as a function of utilization of specific drugs. A key goal of the ALERT project is to distinguish between “true” and “false” signals of potential ADEs. ALERT is being carried out by a consortium of 18 European research institutions and is coordinated by Erasmus University Medical Center in the Netherlands (PharmacoEpi & Risk Management Newsletter, 2009).

Another example of an EU project relevant to medication management is the CIP ICT PSP Work Programme, which funds projects for interoperability of e-Health solutions across national borders. One effort funded under this program, the European Patients Smart Open Services project, aims to increase the interoperability of patient summaries and e-prescriptions. It is a collaborative of 12 EU-member states that will develop, test, and validate key specifications such as interoperability among health information systems. One of the practical motivators for this project is the frequent, cross-border travel in which many Europeans engage on a regular basis. European physicians often treat patients from other countries with limited access to their health information. Goals of this project include helping providers address the practical challenges of treating patients from other countries, such as being able to refill lost or forgotten medications and communicating medical information to physicians who speak different languages (European Commission ICT for Health, 2006).

Finally, the EU’s Ambient Assisted Living (AAL) program is designed to improve the quality of life of older adults through use of information and communication technology. One of the unique projects supported through AAL is the Hear Me Feel Me project. This project uses radio frequency identification (RFID) tags on medications and a RFID reader attached to smart mobile phones to help visually impaired individuals, including older adults, identify medications. This system also provides audio instructions to help older adults and visually impaired individuals improve and document medication adherence (Ambient Assisted Living, 2010).

References

Agency for Healthcare Research and Quality (2001). Making healthcare safer: A critical analysis of patient safety. Rockville, M.D.: U.S. Department of Health and Human Services. AHRQ Publication 01-E058. http://www.ahrq.gov/clinic/ptsafety/pdf/ptsafety.pdf. Accessed April 3, 2012.

Agency for Healthcare Research and Quality (2010). Enabling medication management through health IT: Review protocol. Rockville, MD: U.S. Department of Health and Human Services. http://www.ahrq.gov/clinic/tp/medmgttp.htm. Accessed April 3, 2012.

Agency for Healthcare Research and Quality. (2010). Home Health Nurses and Care Managers Use Software-Aided Medication Review Protocol for Frail, Community-Dwelling Seniors, Leading to More Appropriate Medication Use. http://www.innovations.ahrq.gov/content.aspx?id=2841. Accessed May 30, 2012.

Ambient Assisted Living (2006). The R&D funding programme addressing demographic ageing in Europe. http://www.aal-europe.eu/Published/pr-docs/flyer-aal-call-1-projects. Accessed April 3, 2012.

American Psychological Association (2011). Disability and socioeconomic status. http://www.apa.org/pi/ses/resources/publications/factsheet-disability.aspx. Accessed April 3, 2012.

American Society of Consultant Pharmacists (2010). ASCP fact sheet. https://www.ascp.com/articles/about-ascp/ascp-fact-sheet. Accessed April 3, 2012.

Ammenwerth, E., Schnell-Inderst, P., Machan, C., Siebert, U. (2008). The effect of electronic prescribing on medication errors and adverse drug events: A systematic review. *Journal of American Medical Informatics Association,* 15(5), 585-600.

Barker, K.N., Flynn, E.A., Pepper, G.A., Bates, D.W., Mikeal, R.L. (2002). Medication errors observed in 36 health care facilities. *Archives of Internal Medicine,* 162(16), 1897-1903.

Bates D.W., Cullen, D.J., Laird, N., Petersen, L.A., Small, S.D., Servi, D., Laffel, G., Sweitzer. B.J., Shea, B.F., Hallisey, R., Vander Vliet, M., Nemeskal, R., Leape, L. (1995). Incidence of adverse drug events and potential adverse drug events. *Journal of the American Medical Association,* 307(12), 1229-1329.

Bell, D.S., Friedman, M.A. (2005). E-prescribing and the Medicare Modernization Act of 2003. *Health Affairs,* 24(5), 1159-1169.

Bootman, J.L., Harrison, D.L., Cox, E. (1997). The health care cost of drug-related morbidity and mortality in nursing facilities. *Archives of Internal Medicine,* 157(18), 2089-2096.

Buckwalter, K.C., Wakefield, B.T., Hanna, B., Lehman, J. (2004). New technology for medication adherence: Electronically managed medication dispensing system. *Journal of Gerontological Nursing,* 30(7), 5-8.

Casey, M.M., Sorensen, T.D., Elias, W., Knudson, A., and Gregg, W. (2010). Current practice and state regulations regarding telepharmacy in rural hospitals. *American Journal of Health-System Pharmacy* 69(8), 1085-1092.

Center for Connected Health (2010). Wireless medication adherence: Reminders and incentives improve adherence. http://www.connected-health.org/media-center/press-releases/wireless-medication-adherence-study-conducted-at-the-partners-center-for-connected-health-shows-promising-initial-findings.aspx. Accessed April 3, 2012.

Center for Improving Medication Management, eHealth Initiative (2008). Electronic prescribing: Becoming mainstream practice. http://www.thecimm.org/PDF/eHI_CIMM_ePrescribing_Report_6-10-08.pdf. Accessed April 3, 2012.

Center for Technology and Aging (2009). Technologies for optimizing medication use in older adults. http://www.techandaging.org/MedOpPositionPaper.pdf. Accessed April 3, 2012.

Chorost, M. (2008). The networked pill: A new information system records what pills do to the body. Technology Review. http://www.technologyreview.com/biotech/20434/. Accessed April 3, 2012.

Clinical Update (2009). Strategies to reduce medication errors in older adults. *Australian Nursing Journal,* 17(3), 30-33.

Conn, V.S., Hafdahl, A.R., Cooper, P.S., Ruppar, T.M., Mehr, D.R., Russell, C.L. (2009). Interventions to improve medication adherence among older adults: Meta-analysis of adherence outcomes among randomized controlled trials. *The Gerontologist,* 49(4), 447-462.

Ernst, E.R., Grizzle, A.J. (2001). Drug-related morbidity and mortality: updating the cost-of-illness model. *Journal of American Pharmaceutical Association*, 41(2), 192-199.

European Commission ICT for Health (2006). ICT for sustainable and interoperable health services. http://ec.europa.eu/information_society/activities/health/cip_ict_psp/index_en.htm. Accessed April 3, 2012.

Field, T.S., Rochon, P., Lee, M., Gavendo, L., Baril, J.L., Gurwitz, J.H. (2009). Computerized clinical decision support during medication ordering for long-term care residents with renal insufficiency. *Journal of the American Medical Informatics Association,* 16(4), 480-485.

First Consulting Group, "Computerized Physician Order Entry: Costs, Benefits, and Challenges -- A Case Study Approach." Report prepared for the Massachusetts Technology Collaborative & New England Healthcare Institute, Fall 2004.

Fuson, S. (2010). Choosing a medication reminder system. Today's Caregiver. http://www.caregiver.com/channels/medication/articles/medication_reminder_system.htm. Accessed April 3, 2012.

Gellad, W.F., Grenard, J., McGlynn, E.A. (2009). A review of barriers to medication adherence: A framework for driving policy options. http://www.rand.org/content/dam/rand/pubs/technical_reports/2009/RAND_TR765.pdf. Accessed April 3, 2012.

Gurwitz, J.H., Field, T.S., Harrold, L.R., Rothschild, F., Debellis, K., Seger, A.C., Cadoret, C., Fish, L.S., Garber, L., Kelleher, M., Bates, D.W. (2003). Incidence and preventability of adverse drug events among older persons in the ambulatory setting. *Journal of the American Medical Association,* 289(9), 1107-1116.

Handler, S.M., Hanlon, J.T., Perera, S., Saul, M.I., Fridsma, D.B., Visweswaran, S., Studenski, S.A., Roumani, Y.F., Castle, N.G., Nace, D.A., Becich, M.J. (2008). Assessing the performance characteristics of signals used by a clinical event monitor to detect adverse drug reactions in the nursing home. *American Medical Informatic Association Annual Symposium Proceedings Archive*, 6, 278-282.

Harjivan, C., Lyles, A. (2002). Improved medication use in long-term care: Building on the consultant pharmacist's drug regimen review. *The American Journal of Managed Care*, 8(4), 318-326.

Healthcare Information and Management Systems Society (2011). Electronic health record. http://www.himss.org/ASP/topics_ehr.asp. Accessed April 3, 2012.

Hillestad, R., Bigelow, J., Bower, A., Girosi, F., Meili, R., Scoville, R., Taylor, R. (2005). Can electronic medical record systems transform health care? Potential health benefits, savings, and costs. *Health Affairs,* 24(5), 1103-1117.

Hirschler, B. (2010). Look out, your medicine is watching you. Reuters. http://www.reuters.com/article/2010/11/08/us-summit-novartis-proteus-idUSTRE6A754720101108. Accessed April 3, 2012.

Hughes, R.G., Blegen, M.A. (2008). Medication Administration Safety. In R. G. Hughes, *Patient Safety and Quality: An Evidence-Based Handbook for Nurses*, 396-411, Rockville, M.D.: U.S. Department of Health and Human Services.

Huo, X., Ghovanloo, M. (2007). A wireless pharmaceutical compliance monitoring system based on magneto-inductive sensors. *IEEE Sensors Journal,* 6(12), 1711-1719.

Institute of Medicine (2006). Medication errors injure 1.5 million people and cost billions of dollars annually. http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=11623. Accessed April 3, 2012.

Institute of Medicine (2006). Preventing medication errors reporting brief. http://www.iom.edu/~/media/Files/Report%20Files/2006/Preventing-Medication-Errors-Quality-Chasm-Series/medicationerrorsnew.ashx. Accessed April 3, 2012.

Kaushal, R., Jha, A.K., Franz, C., Glaser, B., Kuperman, G.J., Khorasani, R., Tanasijevic, M., Bates, D.W. (2006). Return on investment for computerized physician order entry systems. *Journal of the American Medical Informatics Association,* 13(3), 261-266.

Kawamoto, K., Houlihan, C.A., Balas, E.A., Lobach, D.F. (2005). Improving clinical practice using clinical decision support systems: A systematic review of trials to identify features critical to success. *British Medical Journal,* 330(7494), 765.

Kimber, M.B., Peterson, G.M. (2006). Telepharmacy -- Enabling technology to provide quality pharmacy services in rural and remote communities. *Journal of Pharmacy and Research*, 36(2), 128-133.

Kripalani, S., Jackson, A.T., Schnipper, J.L., Coleman, E.A. (2007). Promoting effective transitions of care at hospital discharge: A review of key issues for hospitalists. *Journal of Hospital Medicine,* 2(5), 314-323.

Law, T., Ma, B., Icuss, J., Klopfer, M. (2008). In-Home Automated Medication Management and Dispensing System. 2007-2008 RERC-AMI Student Design Competition, University of California, Irvine, Henry Samueli School of Engineering.

Lundell, J., Hayes, T.L., Vurgun, S., Ozertem, U., Kimel, J., Kaye, J., Guilak, F., Pavel., M. (2007). Continuous activity monitoring and intelligent contextual prompting to improve medication adherence. 29th Annual International Conference of the IEEE in Medicine and Biology Society, 6286-6289.

Maviglia, S.M. ,Yoo, J.Y, Franz, C., Featherstone, E., Churchill, W., Bates, D.W., Gandhi, T.K., Poon, E.G. (2007). Cost-benefit analysis of a hospital pharmacy bar code solution. *Archives of Internal Medicine,* 167(8), 788-794.

Meredith, S., Feldman, P.H., Frey, D., Hall, K., Arnold, K., Brown, N.J., Ray, W.A. (2001). Possible medication errors in home healthcare patients. Journal of the American Geriatric Society, 49(6), 719-724.

Meredith, S., Feldman, P., Frey, D., et al. (2002). Improving medication use in newly admitted home healthcare patients: a randomized controlled trial. Journal of the American Geriatrics Society, 50(9), 1484-91.

Murray, M.D., Morrow, D.G., Weiner, M., Clark, D.O., Tu, W., Deer, M.M., Brater, C, Weinberger, M. (2004). A conceptual framework to study medication adherence in older adults. *American Journal of Geriatric Pharmacology,* 2(1), 36-41.

National Academy of Sciences (2007). Preventing medication errors: Quality chasm series. http://www.nap.edu/catalog/11623.html. Accessed April 3, 2012.

National Council on Patient Information and Education (2007). Enhancing prescription medication adherence: A national action plan. http://www.talkaboutrx.org/documents/enhancing_prescription_medicine_adherence.pdf. Accessed April 3, 2012.

New England Healthcare Institute (2009). Thinking outside the pillbox: A system-wide approach to improving patient medication adherence for chronic disease http://www.nehi.net/publications/44/thinking_outside_the_pillbox_a_systemwide_approach_to_improving_patient_medication_adherence_for_chronic_disease. Accessed April 3, 2012.

Oren, E., Shaffer, E.R., Guglielmo, B.J. (2003). Impact of emerging technologies on medication errors and adverse drug events. *American Journal of Health-System Pharmacists,* 60(14), 1447-1457.

Osterberg, L., Balschke, T. (2005). Adherence to Medication. *The New England Journal of Medicine*, 353(5), 487-497.

Peterson, C.D., Anderson, H.C. (2002). Chapter 10: Telepharmacy. http://www.ndsu.edu/fileadmin/telepharmacy/TELEPHARMACY-TAD1.pdf. Accessed April 3, 2012.

PharmacoEpi & Risk Management Newsletter. (2009). Alert: An EU funded multi-national project to integrate electronic health records for the early detection and investigation of adverse drug events. http://www.registratmapi.com/Files/PRMNL_Issue_01.pdf. Accessed April 3, 2012.

Poon, E.G., Keohane, C.A., Yoon, C.S., Ditmore, Mm, Bane, Am, Levtzion-Korach, Om, Moniz, Tm, Rothschild, J.M., Kachalia, A.B, Hayes, J., Churchill, W.W., Lipsitz, S., Whittemore, A.D., Bates, D.W., Gandhi, T.K. (2010). Effect of bar-code technology on the safety of medication administration. *The New England Journal of Medicine*, 362(18), 1698-1707.

Patient Safety Through Intelligent Procedures in Medication (2010). Patient safety through intelligent procedures in medication. http://ec.europa.eu/information_society/activities/health/docs/monthly_focus/2010/2010summer-psip.pdf. Accessed April 3, 2012.

Schafer, S.L. (2001). Prescribing for seniors: It's a balancing act. *Journal of the American Academy of Nurse Practitioners,* 13(3), 108-112.

Schlosberg, C. (2008). Medication-related problems in older adults: A hidden and costly epidemic. Submitted to the transition team of President-Elect Barack Obama http://otrans.3cdn.net/bd998a419a704bbae5_jrm6i2qti.pdf. Accessed April 3, 2012.

Sherman, J. (2007). Telepharmacy -- A promising alternative for rural communities. *Pharmacy Times;* 73(2), 65-86.

Simon, S.R., Smith, D.H., Feldstein, A.C., Perrin, N., Yang, X., Zhou, Y., Platt, R., Soumerai, S.B. (2006). Computerized prescribing alerts and group academic detailing to reduce the use of potentially inappropriate medications in older people. *Journal of the American Geriatrics Society,* 54(6), 963-968.

Subramanian, S., et al. (2012). Immediate financial impact of computerized clinical decision support for long-term care residents with renal insufficiency: a case study. *Journal of the American Medical Informatics Association,* 19(3), 439-42.

Takacs, B., Hanak, D. (2008). A prototype home robot with an ambient facial interface to improve drug compliance. *Journal of Telemedicine and Telecare*, 14(7), 393-395.

Tang, L., Zhou, X., Yu, Z., Zhang, D., Ni, H. (2010). Adaptive prompting based on petri net in a smart medication system. 8th Annual Institute of Electrical and Electronics Engineers International Conference, Pervasive Computing and Communications Workshops, 328-333.

Taylor, L., Tamblyn, R. (2004). Reasons for physician non-adherence to electronic drug alerts. *Studies in Health Technologies and Informatics,* 107(Part 2), 1101-1105.

Tsai, P.H., Yeh, H.C., Yu, C.Y., Hsiu, P.C., Shih, C.S. (2006). Compliance enforcement of temporal and dosage constraints. 27th Institute of Electrical and Electronics Engineers International Real Time Systems Symposium, 359-368.

Wakefield, B.J., Orris, L.J., Holman, R.E., Russell, C.L. (2008). User perceptions of in-home medication dispensing devices. *Journal of Gerontological Nursing,* 34(7), 15-24.

Wang, M.-Y., Zao, J.K., Tsia, P.H., Liu, J.W.S. (2009). Wedjat: A mobile phone based medicine in-take reminder and monitor. 8th Institute of Electrical and Electronics Engineers International Conference on Bioinformatics and Bioengineering, 423-430.

Winland-Brown, J.E., Valiente, J. (2000). Effectiveness of different medication management approaches for elders' medication adherence. *Outcomes Management for Nursing Practice,* 4(4), 172-176.

CHAPTER 4: COGNITIVE IMPAIRMENTS

4.1. Definition of Cognitive Impairments

Cognitive impairments are driven by a number of conditions that adversely impact the ability to think, remember, reason, and quickly process information (National Institutes of Health, 2010). Although cognitive impairments can affect younger individuals, they are observed more frequently among older adults who may experience declines in cognitive ability over time (Deary et al., 2009) and who are the primary focus of this Report. Symptoms of cognitive impairments can vary widely among affected individuals. The range of symptoms can result in relatively minor impairments that have a limited impact on daily life, as well as more severe and increasing challenges resulting in the need for nursing-home care. Although cognitive impairment in older adults occurs on a continuum and can change over time, three categories are often used to describe these conditions among this population: normal cognitive aging, mild cognitive impairment, and dementia (National Institutes of Health, 2010).

Normal cognitive aging describes declines in memory, problem-solving skills, and information-processing speed that occur with advancing age (Anstey and Low, 2004). Despite the age-related declines that often accompany normal cognitive aging, innate intelligence is not affected in most individuals (Burke and Shafto, 2008). Normal cognitive aging can result in minor inconveniences such as difficulty finding items around the house, as well as more serious problems such as forgetting to take medications (Ball, Ross, and Viamonte, 2009).

Mild cognitive impairment (MCI) involves deficits in memory, language, thinking, and judgment that are greater than those observed among individuals with normal cognitive aging (Mayo Clinic, 2010). Symptoms of MCI are generally not severe enough to significantly affect performance of activities of daily living (ADLs) such as bathing and eating, nor are they sufficient to meet the threshold for dementia. Nevertheless, MCI is considered a transitional stage between normal cognitive aging and dementia, making this category of cognitive impairment a meaningful marker for future dementia risk, as well as a potential point at which interventions to address cognitive decline should be initiated (Petersen et al., 2009).

Dementia is characterized by cognitive impairment that is chronic, progressive, and irreversible (Fillit et al., 2002). It affects critical cognitive abilities such as retrospective and prospective memory, as well as executive functions such as goal formulation, planning, organizing, and abstract reasoning (Rockwood, 2002). In addition, dementia patients often exhibit mood fluctuations and confusion. Further, they may engage in wandering behaviors such as nighttime walking or elopement, a term used to describe a patient's departure from a treatment setting (including the home) when the departure could threaten the safety of the patient or others (Landau et al., 2010). Unlike MCI, dementia often involves a pathological decline in memory and other cognitive abilities that are sufficiently severe to interfere with ADLs, making it a risk factor for loss of independence. Alzheimer's Disease (AD) is the most common cause of dementia, especially late in life. AD is characterized by the development of plaques and tangles in the brain that lead to widespread cognitive impairment and brain tissue atrophy. Vascular dementia, the second most common type of dementia, results from impaired blood flow to the brain that restricts the supply of oxygen and energy required for normal cognitive function (Alzheimer's Association, 2010).

Cognitive impairment is associated with a host of problems that impact health-care professionals, patients, and caregivers. Examples of problems affecting health-care professionals include a lack of access to the information needed to ascertain the presence and degree of cognitive impairment, as well as challenges associated with identifying clinically meaningful changes in cognition over time that are part of a progressive loss of function, which are often referred to collectively as cognitive decline. Problems affecting patients include difficulties in preventing and slowing cognitive decline, compensating for cognitive losses once they have occurred, and maintaining social networks as cognition diminishes and social isolation increases. Caregivers of people with cognitive impairments also experience substantial challenges in caring for these individuals. These include concerns about safety, maintaining communication with the affected individual, and being able to identify changes in behavior or other factors that might indicate that additional services or caregiving are needed. A number of technologies are available and under development that address one or more of these problems.

4.2. Prevalence of Cognitive Impairment

As the name implies, many view normal cognitive aging as a routine aspect of advancing age. It is not considered a disease, nor is it associated with diagnostic codes that facilitate ascertainment of its prevalence. It is therefore difficult to quantify the occurrence of normal cognitive aging since it is not broadly viewed as a deviation from "normal," it does not present outwardly or with obvious or visible symptoms, and it is not a diagnosable condition (Ball, Ross, and Viamonte, 2009). However, updates to diagnostic criteria that are scheduled for release in the spring of 2012 are expected to recognize both the existence and continuum of geriatric cognitive disorders. The new criteria distinguish among mild and major MCI (which will be renamed 'neurocognitive disorder') associated with AD, frontal lobe damage or degeneration, vascular diseases, Parkinson's Disease, and other conditions that can impair cognition. The revisions also recognize the gradual progression from mild to major cognitive impairment and the reality that major cognitive impairment may predict future AD diagnosis (American Psychiatric Association, 2012).

In contrast to the difficulty associated with quantifying normal cognitive aging, a number of sources provide reliable estimates of other forms of cognitive impairment. One study suggested that over 22 percent of people over age 71 in the U.S. (an estimated 5.4 million individuals) have MCI that has not progressed to dementia or AD (Plassman et al., 2008). A recent study estimated that the prevalence of MCI among older adults without dementia was 16 percent, and that 10 to 15 percent of these patients progressed to dementia over three years (Petersen et al., 2010). Another study reported that, over four years, progression to dementia occurred in 50 percent of MCI patients. This research also showed that between 5 to 8 percent of otherwise healthy older adults develop MCI each year (Lopez et al., 2007). People with MCI that includes memory deficiencies have an especially high progression rate to AD, rendering this combination of symptoms of particular concern for development of severe cognitive impairment and decline in old age (Bell, 2007).

In 2011, an estimated 14 percent of individuals age 71 and older had been diagnosed with dementia. The prevalence of dementia increases dramatically with age: while only 5 percent of adults age 71 to79 are diagnosed with dementia, this figure rises to 37 percent among people age 90 and older. Women are at greater risk of dementia due in large part to their longer life spans. The prevalence of dementia among women age 71 and above has been estimated at 16 percent, compared to 11 percent among men (Plassman et al., 2007). Similarly, cumulative lifetime risk of dementia ranges from 17 to 21 percent among women, and 9 to 17 percent among men. There are data to suggest that the incidence of dementia also varies by race, with African Americans twice as likely and Hispanics about 1.5 times as likely as whites to be diagnosed with this condition (Alzheimer’s Association, 2010a).

AD accounts for approximately 70 percent of dementia cases (Plassman et al., 2007), and affects an estimated 5.1 million individuals age 65 and older, a figure representing 13 percent of this age group (Herbert et al., 2003). AD is the fifth-leading cause of death among people age 65 and older and the sixth-leading cause of death in the U.S. After diagnosis, individuals over the age of 60 live an average of four to six years (Larson et al., 2004). Early-onset AD occurs in people under age 65 and currently affects approximately 200,000 Americans (Alzheimer’s Association, 2011a). In addition to its earlier onset, this is a more aggressive form of AD that generally causes faster cognitive decline (Canu et al., 2010).

4.3. Costs and Burdens Associated with Cognitive Impairment

Cognitive impairments and decline result in increased health-care costs, elevated risk of disability, and decreases in work efficiency and quality of life (Plassman et al., 2008). Although the consequences of cognitive impairment are most pronounced among people with dementia, they are also present among those with MCI and normal cognitive aging. AD and dementia are responsible for significant costs to the U.S. health-care system. The results of a 2003 review indicate that costs for the care of AD patients alone totaled an estimated $100 billion. Per patient, total annual costs (direct and indirect) can range from $1,500 to $91,000, depending on the medical and caregiving services required, symptom severity, and other comorbid diagnoses (Bloom, de Pouvourville, and Straus, 2003). With the aging of the U.S. population, these costs are expected to grow from $183 billion in 2011 to $1.1 trillion in 2050 (in 2011 dollars)" (Alzheimer's Association, 2011a). Long-term care, respite care, short-term stays in adult day-care facilities, and in-home care all contribute to the high cost of caring for people with AD. One study noted that the highest monetary costs incurred in the treatment of AD arise from extended nursing-home stays (Hux et al., 1998). Two-thirds of people who die from AD will do so in a nursing home (Mitchell et al., 2005). Further, although the clinical manifestation of dementia develops over time, the social isolation that results from the breakdown of the patient's social networks can accelerate cognitive deterioration, thereby exacerbating the patient's clinical profile.

It is not surprising that older adults with dementia consume more health-care resources than do those without this condition, including increased utilization of services in hospitals, assisted-living facilities, nursing homes, special care units, and hospices. Adults with dementia have three times as many hospital stays as do people without dementia and are eight times more likely than Medicare beneficiaries of the same age to require home-health services (Alzheimer's Association, 2011a).

The cost of cognitive impairments extends beyond patients to both businesses and caregivers. Businesses incur substantial costs associated with employees attempting to both work and provide care to loved ones due to absenteeism, lost productivity, and costs to replace employees who leave or lose their jobs (Alzheimer's Association, 2002). There are also significant costs to the families of people with cognitive impairments, AD, and dementia because they provide the majority of informal care to affected individuals who live primarily in the community. One review article estimates that 80 percent of community-dwelling AD patients require informal care and that the indirect cost of this care to family members is three times higher than the cost of their formal care (Oremus and Aguilar, 2011).

In addition to its financial consequences, cognitive impairment often takes an emotional toll on families for extended periods of time. People with advanced dementia frequently do not recognize and are not comfortable with family and friends, which can generate tremendous, prolonged stress for both patients and families. Spouses and children in particular often experience a sense of loss in response to the affected person's deterioration.

The progressive, debilitating nature of dementia often disrupts normal family life. Family members may have to make dramatic changes to provide adequate care for the affected individual at home. Behaviors such as wandering and agitation add to these burdens. People in the advanced stages of dementia often require full-time care and continuous monitoring. Caring for an individual with dementia is taxing in terms of time, emotion, and finances. As a result, caregivers of people with dementia have more medical conditions than do those who do not have these responsibilities. Their caregiving role is associated with increased medication use, anxiety, depression, decreased self-efficacy, and impaired metabolic function (Sörensen et al., 2006), as well as slow wound healing (Kiecolt-Glaser et al., 1995), new hypertension (Shaw et al., 1999) and new coronary heart disease (Vitaliano et al*,* 2002). In another study, 24 percent of spousal caregivers had an emergency department visit or hospitalization in the previous six months (Schubert et al., 2008). All of these consequences are associated with treatment costs of their own, further highlighting the impact of cognitive impairment on health resource utilization.

4.4. Available Technologies for Cognitive Impairment and Evidence of Their Benefits

Technologies addressing cognitive impairments target a variety of problems. Most of these are directed at patients and caregivers in the community, where most patients reside and where most caregiving occurs. In general, technologies aimed at prevention target healthy, normally aging adults who want to stay mentally "sharp." Typically, these technologies seek to maintain or improve existing cognitive function through training exercises. Technologies focused on detection of cognitive impairments and/or decline target adults with normal cognitive aging as well as persons with dementia. These technologies focus on identification of behavioral, cognitive, or physical symptoms of cognitive impairment and decline, and are intended to help users maintain independence, assist caregivers, and inform care. Intervention-oriented technologies assist adults with existing MCI, dementia, or AD. These technologies attempt to slow the progression of cognitive decline (e.g., from MCI to dementia, or from mild to moderate dementia), track the progression of symptoms, and support adults with diminished cognitive abilities.

Prevention

Technologies aimed at preventing cognitive impairment and decline focus heavily on cognitive training exercises that target specific aspects of cognitive functioning such as memory, attention, and language. Computer-based cognitive training aims to maintain cognitive function, thereby reducing risk of decline. In this general approach, well-studied paper-and-pencil tasks that target abilities such as memory, reasoning, and processing speed are adapted for computer-based use and implemented in computer memory games, puzzles, cognitive exercise, and brain fitness software applications. This type of training is available as software that can be installed on a personal computer, on websites that can be accessed with an internet browser or, in some cases, on dedicated touch-screen computers with easy-to-operate user interfaces. One study explored the efficacy of cognitive training software in a cohort of adults age 65 to 94 and showed that, although computer-based training raised cognitive performance scores, it did not improve ADL performance (Ball et al., 2002). However, certain elements of this training did favorably impact quality of life (Wolinsky et al., 2006).

Randomized controlled studies of technology-enhanced cognitive exercises are limited, but there is some evidence supporting the potential benefit of multi-domain cognitive training in improving cognitive function in healthy older adults and slowing decline in individuals with existing deficits (Gates and Valensuela, 2010). However, studies of the impact of these technologies often focus on memory training and do not target long-term, sustainable gains or transferable cognitive skills. Thus, after initial task-specific improvements, benefits often wane, especially if use of the technology is not sustained (Martin et al., 2011). For example, one study reported that older adults who used commercial brain training software for an hour each day, five days a week, improved on memory measures and processing speed compared to those who did not use the software (Smith et al., 2009). However, these benefits diminished after three months without active training, suggesting a need for sustained, intensive training to maintain the observed improvements (Zelinski et al., 2011). Other studies also support the idea that, in order for users to sustain benefit from these training technologies, they must sustain technology use (Owen et al., 2010).

Social isolation often results from cognitive impairment, making technology-enhanced social interaction an appealing approach to prevention of this common problem among people with cognitive deficits (Fillit et al., 2002). Online social networks, as well as computer- and phone-based communication systems, can provide older adults with opportunities to establish and maintain relationships, particularly if they live alone, are disabled, or have limited access to transportation. These connections can be particularly important for people seeking to prevent the social isolation that often accompanies cognitive impairment. Technologies that address this need include two-way video conferencing, easy-to-use video phones, computers, and connectivity applications such as those employing icons on touch-screen computers. However, the effectiveness of these approaches to reduction of social isolation among people with cognitive impairments has not been rigorously evaluated. Technologies addressing social isolation are discussed further in Chapter 6 of this report, which focuses on depression.

Detection

Early detection of cognitive impairment and decline permits timely intervention and is therefore important for preservation of cognitive health in older adults. Neuropsychological tests--both paper- and computer-based--are the most common performance-based tools used to evaluate cognitive status. Certain symptom evaluation tools can be administered via telephone by a clinician or an automated response system (Mundt et al., 2001) or via personal digital assistants (PDAs) (Moskowitz and Young, 2006). These methods of administration, while “low tech,” are not only valid but also allow clinicians to maintain frequent contact with patients or to assess those who may be otherwise unable or unwilling to access their care provider. Advanced imaging technologies such as computed tomography (CT), positron emission tomography (PET), magnetic resonance imaging (MRI), and functional MRI (fMRI) are also used to identify those susceptible to manifesting cognitive decline and/or cognitive impairment (Fillit et al., 2002).

Cognitive impairment is associated with changes in brain structure and function. Most structures in healthy, aging brains lose 0.5 to 1 percent of their volume each year (Fjell and Walhovd, 2010). Volume loss in dementia and AD is even greater, but is restricted to specific brain regions like the frontal lobe (Tartaglia, Rosen, and Miller, 2011). These structural changes can be identified by CT (Tartaglia, Rosen, and Miller, 2011) and MRI scans (Frisoni et al., 2009). Further, structural changes in the brain allow these technologies to successfully distinguish among MCI, dementia, and AD (McEvoy et al., 2009). Whereas CT and MRI can detect changes in brain structure, neuroimaging with PET or fMRI can detect differences in brain activity patterns (Kalpouzos et al., 2009; Beason-Held, Kraut, and Resnick, 2006; Machulda et al., 2003). Identifying these fMRI patterns helps researchers and physicians characterize MCI, dementia, and AD in a manner that facilitates diagnosis and care planning for patients.

In addition to imaging techniques, home-based activity monitoring also offers opportunities to detect cognitive impairment. These systems use sensors embedded in the environment to detect changes in activity levels, habits, and other behaviors that can indicate cognitive impairment. These systems are described in greater detail in Chapter 1, which focuses on falls and fall prevention, another care issue that is targeted with these monitoring systems. One study analyzed utilization data from keyboards, mice, and software application use to identify patterns associated with cognitive impairment. This study found that computer use, typing speed, and variability in performance predicted cognitive impairment, suggesting that monitoring these performance-based activities might yield patterns that are indicative of meaningful changes in cognition (Jimison et al., 2006). Other studies have shown that in-home motion sensors can identify activities and movements (e.g., variability in walking speed and abnormalities in gait) that are markers of MCI and dementia (Hayes et al., 2008; Suzuki and Murase, 2010). These preliminary results suggest that larger studies may be helpful in elucidating how best to implement these preventive approaches in practice and whether they provide clinically relevant benefits with respect to cognitive impairment (Kaye et al., 2011).

Intervention

Older adults experiencing cognitive impairment and decline may benefit from technology-enhanced memory supports that compensate for memory deficits (LoPresti, Mihailidis, and Kirsch, 2004). Some of these technologies help patients keep track of event- and time-based information. Planning and Execution Assistant and Trainer (PEAT) software is one example of this type of technology. PEAT is a customized system that integrates personal cueing such as digital pictures and voice recordings. The software is intended to help users keep deadlines and appointments, thereby helping to sustain activity and minimize caregiver burden. Although these devices are promising interventions for MCI and dementia patients, their efficacy has not been established (Seelye et al., 2009).

Memory aids are another class of technologies that support cognition by helping the patient to maintain memories (Cipriani, Bianchetti, and Trabucchi, 2006). The Digital Family Portrait is an example of this type of technology. This memory aid provides images that visually summarize events of the previous few days (Mynatt et al., 2001). Although patients with severe cognitive impairment may have difficulty with the training needed for the effective use of these types of memory aids, studies have shown that patients with mild to moderate dementia can be trained to use these technologies. Further, there is evidence to suggest that adoption of these tools can help older adults maintain their independence (Capriani, Greaney, and Porter, 2006). One study showed that a cognitive rehabilitation program that included memory aids improved both memory and ADL performance in adults with MCI (Kurz et al., 2009).

One challenge caregivers often face is the need to provide basic, ongoing support to affected individuals, including support for tasks such as food preparation and personal hygiene. An intelligent assistive support system is under development that addresses this need by providing guidance on hand-washing to adults with dementia, thereby reducing caregiver burden. Pilot studies indicate that the device helped participants with moderate dementia complete an average of 11 percent more hand-washing steps independently and required 60 percent fewer interactions with a human caregiver related to hand-washing when the system was in use (Mihailidis et al., 2008). While these data suggest promise for a single hygiene-related task, technologies that are able to promote sustained independence in basic activities are important because of their potential for reducing caregiver burden.

In addition to their utility in detecting cognitive impairment, activity-monitoring technologies have also been used among people with established cognitive deficits. One example of this application is among patients who engage in dangerous behaviors such as wandering and elopement (Altus et al., 2000). Monitoring technologies mitigate the risks associated with these behaviors by facilitating remote patient monitoring. This approach not only provides physical security to the patient, but it also provides emotional security to caregivers and reduces caregiver burden by allowing the caregiver to monitor a loved one from a location of their choosing. A variety of technologies can be employed in patient monitoring systems. These include global positioning systems (GPS), radio frequency (RF) transmitters, and cellular-based tracking devices. In one system, a GPS is embedded in shoes that allow the user's location to be tracked with a secure subscriber's portal. Other systems integrate more than one technology to address these behaviors. Assisted GPS systems (AGPS), which combine GPS and cellular tracking functionalities, can provide greater accuracy, availability, and coverage than standard GPS (Djuknic and Richton, 2001). Similar devices for monitoring and tracking involve radio transmitter- and receiver-based systems.

To support tracking or "wander monitoring" efforts, the Alzheimer's Association has created its own web-based location service. The system uses the internet and a tracking device of the family's choice to identify the location of a person with AD on an ongoing, full-time basis. This system can establish "safety zones" and send alerts to caregivers when a person moves beyond the defined area (Alzheimer's Association, 2011b).

Electronic games are increasingly used to encourage social interaction among older adults with cognitive impairment. These technologies provide diverse platforms for social interaction, and they often include memory exercises and other features directed at specific cognitive issues that are common among these patients. The user-centered design of these technologies aims to retain the characteristics of successful game design for older adults such as simplicity, uncomplicated rules, and participation by more than one individual. Some of these technologies feature mobility and include card games, quizzes, and memory games (Mubin et al., 2008).

Advances in touch screen technology and computer graphics provide novel ways for older adults to manipulate virtual objects. Tabletop user interfaces are one way in which these technologies have been modified for use with cognitively impaired adults. One application of this technology is digital photo-sharing in which a tabletop interface acts as a digital photograph application that allows the user to interact with the object by touching the tabletop surface. This device has no buttons, menus, or toolbars, making it easy to use for older adults with cognitive challenges. This technology can also promote social interaction because multiple users can sit together at the table and use it simultaneously (Apted et al., 2005).

Technologies that focus primarily on meeting caregivers' needs are also available. For example, online support systems that promote communication among fellow caregivers can reduce caregiver isolation and facilitate information-sharing (Czaja and Rubert, 2002). Finally, technology is playing an increasing role in the formal treatment of cognitively impaired adults (Rogers and Mynatt, 2003). Some providers promote integration of technologies such as personal digital assistants (PDA) into their treatment protocols (LoPresti, Mihailidis, and Kirsch, 2004).

4.5. Technologies Under Development to Address Cognitive Impairment

In addition to technologies that are currently available to address cognitive impairment and decline, new solutions are under development that target both patients and caregivers. Users can wear a number of these new technologies, which focus on tracking movements among patients who are prone to wander. For example, one wearable device tracks movement using a combination of sensors including a portable unit that contains a GPS receiver, a cellular Global System for Mobile (GSM) modem, a radio frequency (RF) receiver, and a wristwatch with an RF transmitter. A preliminary assessment of this technology indicated user acceptability as well as the ability of the device to collect high-quality data over long periods of time (Shoval et al., 2010). Another anti-wandering device is embedded in a bracelet worn by the user. It emits a low-level RF that can be used to alert authorities if the user goes missing. Although this device can provide comfort to caregivers and safety to patients who have a tendency to wander, it also has notable weaknesses, including the need for frequent battery checks on the part of the user or a caregiver (Daniel, Cason, and Ferrell, 2009). A general limitation of wearable devices is that they require users to remember to wear the device, which entails a specific cognitive function that is often profoundly compromised in these patients. Further, factors such as the need to check and recharge batteries can also require active user engagement, or ongoing oversight by a caregiver.

Monitoring devices that do not require ongoing user engagement or compliance are appealing to many patients and families. These devices are often embedded in the user's environment in a manner that allows passive activity monitoring and collection of other information that can be transmitted to a caregiver. Some devices also provide tailored prevention, detection, and assistance functions that address the user's specific needs (Intel Corporation, 2003).

"Smart homes" are one application of passive monitoring (Orwat, Graefe, and Faulwasser, 2008). Smart homes rely on technology embedded in the home environment that does not require active user engagement. These homes are designed not only to monitor older adults' activities, but also to provide additional support relevant to cognitive impairment (Cole, 2009). For example, smart homes can incorporate sensors that record the user's movements and reduce the risks associated with wandering. They can also monitor appliances such as stoves, which can be inadvertently left on by people with memory deficits (Cole, 2009). These systems can either transmit data to caregivers who can then take appropriate action when necessary, or provide decision support directly to patients. For instance, a smart home could ascertain that a patient moved from the kitchen without turning off the stove and prompt them to turn off the stove by providing a reminder. Some systems that are currently on the market go one step further and turn appliances on and off automatically.

Smart homes have the potential to be adapted for people with cognitive impairments and could include supportive functions such as labeling systems based on bar codes that identify food or clothing, washing machines that recognize clothes with data tags, universal controllers for appliances, and interactive video monitoring that provides visual cues. One system features reminders that address the forgetfulness associated with age-related cognitive decline. During an initial learning phase, this system collects information on the user's behavior patterns, analyzes this information, and uses it as a basis for providing reminders about routine activities (Cheek, Nikpour, and Nowlin, 2005).

Maintaining social contacts can be an important component of cognitive and emotional health, but can also be a source of anxiety. Social memory aids are another evolving technology that allows individuals with MCI to practice name and face recognition, thereby decreasing social anxiety. The user selects photos that link to a database of personal contacts. Questions and clues about the person in the photo are presented on a TV screen, and the user is prompted to recall information about the individual being displayed. This technology also stores information longitudinally and provides ongoing cognitive assessment based on this information (Morris et al., 2004).

Unlike technologies that primarily target users and caregivers, novel home-monitoring applications (e.g., Project HealthDesign) seek to enhance clinicians' ability to collect and access information that is relevant to early detection of cognitive decline and impairment, as well as to provide effective care for patients with established decline.

For example, one research team is developing a system that will monitor activities including medication adherence, movement, and cooking. This information can be integrated into a personal health record (PHR) accessible to users, caregivers, and clinicians. The goal of this approach is to facilitate early detection of cognitive impairment as well as clinically relevant changes in cognitive function, thereby allowing caregivers and health-care professionals to be proactive about key issues such as treatment and safety.

4.6. Experiences of Other Counties with Technologies for Cognitive Impairment

Although technologies addressing the needs of older adults with cognitive impairments and decline are available internationally, many of these are similar to those found in the U.S. In the EU, systems that monitor people with cognitive impairments are often referred to as "social alarms." One application for social alarm technology targets patients with mild dementia using mobile devices and a base unit that is installed at home. These systems (e.g., Cogknow) provide electronic reminders, a picture dialing phone, safety alerts, mobile navigation for returning home, and web-based management tools. A similar project, funded by the EU Information Technologies Society's Sixth Framework Programme, has released a wearable technology addressing cognitive impairment. This system includes a device that is worn on the wrist and a mobile phone with simplified features that allows the user to maintain contact with health-care and social-service providers. The system is designed to integrate with other assistive technologies, such as activity-monitoring systems installed in the user's home. The device enables older adults to use a variety of applications to address symptoms of cognitive impairment and facilitates monitoring by health-care professionals (ENABLE, 2010).

The SHARE-IT project (Supported Human Autonomy for Recovery and Enhancement of Cognitive and Motor Abilities Using Information Technology) intends to create a variety of modular devices that interact with other assistive technology devices and that can potentially be incorporated into smart home infrastructure for older adults and individuals with disabilities. This project is also funded by the EU Sixth Framework Programme and organizations in several countries such as Germany, Italy, Spain, and Romania. SHARE-IT's broader goals include maintenance of older adults' autonomy, streamlining communication with caregivers, and standardizing measurements to provide accurate sensing, computation, and assistance to the users (European Commission, Community Research and Development Information Service, 2009).

In addition to EU collaborations that focus on older adults with cognitive impairments, a number of European countries have domestic programs that promote social alarms. In Germany, one project provides monitoring and video-conferencing to older adults who are confined to their homes (Empirica, 2010). In the U.K., the National Health Service provides social alarms, although users make a monthly payment toward operating expenses. Support for social alarms in France is more limited. Local governments generally provide alarms, but they are only available in about 25 percent of French counties, and private organizations or fire departments usually provide response services for these alarms. Technologies addressing cognitive impairments are also found in Asia. For example, in Japan, social alarms are available from both local government and private organizations, but response services tend to be contracted to private organizations (Empirica and Work Research Centre, 2010).

References

Altus, D., Mathews, M., Zaverius, P., Engelman, K., Nolan, A. (2000). Evaluating an electronic monitoring system for people who wander. *American Journal of Alzheimer's Disease and Other Dementia*, 15(2), 121-125.

American Psychiatric Association (2012). DSM-5 development, proposed revisions: Neurocognitive disorders. http://www.dsm5.org/proposedrevision/Pages/NeurocognitiveDisorders.aspx. Accessed April 5, 2012.

Alzheimer's Association (2002). Alzheimer's Disease: The costs to U.S. businesses in 2002. http://www.alz.org/national/documents/report_alzcosttobusiness.pdf. Accessed April 5, 2012.

Alzheimer's Association (2010). 2010 Alzheimer's disease facts and figures. http://www.alz.org/documents_custom/report_alzfactsfigures2010.pdf. Accessed April 5, 2012.

Alzheimer's Association. (2011a). 2011 Alzheimer's disease facts and figures. http://www.alz.org/downloads/Facts_Figures_2011.pdf. Accessed April 5, 2012.

Alzheimer's Association (2011b). Comfort Zone. http://www.alz.org/comfortzone/. Accessed April 5, 2012.

Anstey, K. Low, L.F. (2004). Normal cognitive changes in aging. *Australian Family Physician,* 33(10), 783-787.

Apted, T., Kay, I., Quigley, A. (2006). Tabletop sharing of digital photographs for the elderly. SIG HI Conference on Human Factors in Computing Systems, 781-790.

Ball, K., Berch, D.B., Helmers, K.F., Jobe, J.B., Leveck, M.D., Marsiske, M., Morris, J.N., Rebok, G.W., Smith, D.M., Tennstedt, S.L., Unverzagt, F.W., Willis, S.L. (2002). Effects of cognitive training interventions with older adults: A randomized controlled trial. *Journal of the American Medical Association,* 288(18), 2271-2281.

Ball, K., Ross, L.A., Viamonte, S.M. (2009). Normal aging and everyday functioning. In T.D. Marcotte, I. Grant, *Neuropsychology of everyday functioning*, 248-264. New York City, New York: Guilford Press.

Beason-Held, L.L., Kraut, M.A., Resnick, S.M. (2006). Longitudinal changes in aging brain function. *Neurobiology of Aging,* 29(4), 483-496.

Bell, K. (2007). Mild Cognitive Impairment. In K. Marder and J.C.M. Brust, *Current Diagnosis and Treatment in Neurology: Dementia & Memory Loss*, Second Edition, 85. New York City, NY: McGraw-Hill.

Bloom, B.S., de Pouvourville, N., Straus, W.L. (2003). Cost of illness of Alzheimer's Disease: How useful are current estimates? *The Gerontologist*, 43(20), 158-164.

Burke, D.M., Shafto, M.A. (2008). Language and Aging. In F.I.M. Craik, T.A. Salthouse, *The handbook of aging and cognition, 3rd Edition*, 373-443. London, England: Psychology Press.

Canu, E., Frisoni, G.B., Agosta, F., Pievani, M., Bonetti, M., Filippi, M. (2010). Early and late onset Alzheimer's disease patients have distinct patterns of white matter damage. *Neurobiology of Aging,* epublication.

Capriani, N., Greaney, J., Porter, N. (2006). A review of memory aid devices for an ageing population. *PsychNology Journal ,* 4(3), 205-243.

Cheek, P., Nikpour, L., Nowlin, H. (2005). Aging well with smart technology. *Nursing Administration Quarterly,* 29(4), 329-338.

Cipriani, G., Bianchetti, A., Trabucchi, M. (2006). Outcomes of a computer-based cognitive rehabilitation program on Alzheimer's disease patients compared with those on patients affected by mild cognitive impairment. *Archives of Gerontology and Geriatrics*, 43(3), 327-335.

Cole, D. (2009). Researchers see 'Smart Homes' as safety net for elderly. Washington State University, Journal of Business. http://school.eecs.wsu.edu/node/830. Accessed April 5, 2012.

Czaja, S.J., Rubert, M.P. (2002). Telecommunications technology as an aid to family caregivers of persons with dementia. *Psychosomatic Medicine*, 64(3), 469-476.

Daniel, K., Cason, C., Ferrell, S. (2009). Emerging technologies to enhance the safety of older people in their homes. *Geriatric Nursing,* 30(6), 384-389.

Deary, I.J., Corley, J., Gow, A.J., Harris, S.E., Houlihan, L.M., Marioni, R.E., Penke, L., Rafnsson, S.B., Starr, J.M. (2009). Age-associated cognitive decline. *British Medical Bulletin,* 92(1), 135-152.

Djuknic, G. Richton, R. (2001). Geolocation and assisted GPS. *Computer,* 34(2), 123-125.

Empirica (2010). The SOPHIA telecare service--Telecare deployment model addressing housing organizations. http://www.ict-ageing.eu/?page_id=1353. Accessed April 5, 2012.

Empirica and Work Research Centre (2010). ICT and ageing: European study on users, markets and technologies. http://www.ict-ageing.eu/ict-ageing-website/wp-content/uploads/2010/D18_final_report.pdf. Accessed April 5, 2012.

ENABLE (2010). Enable Product Overview. http://www.enable-project.eu/. Accessed April 5, 2012.

European Commission, Community Research and Development Information Service (2009). Supported human autonomy for recovery and enhancement of cognitive and motor abilities using information technologies (SHARE-IT). http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_RCN=9076822. Accessed April 5, 2012.

Fillit, H.M., Butler, R.N., O'Connell, A.W., Albert, M.S., Birren, J.E., Cotman, C.W., Greenough, W.T., Gold, P.E., Kramer, A.F., Kuller, L.H., Perls, T.T., Sahagan, B.G., Tully, T. (2002). Achieving and maintaining cognitive vitality with aging. *Mayo Clinic Proceedings,* 77(7), 681-696.

Fjell, A.M. Walhovd, K.B. (2010). Structural brain changes in aging: Courses, causes and cognitive consequences. *Reviews in Neuroscience,* 21(3), 187-221.

Frisoni, G.B., Fox, N.C., Jack, C.R.Jr., Scheltens, P., Thompson, P.M. (2009). The clinical use of structural MRI in Alzheimer's disease. Nature Reviews Neurology, 6, 67-77.

Gates, N., Valenzuela, M. (2010). Cognitive exercise and its role in cognitive function in older adults. *Current Psychiatry Reports,* 12(1), 20-27.

Hayes, T.L., Abendroth, F., Adami, A., Pavel, M., Zitzelberger, T.A., Kaye, J.A. (2008). Unobtrusive assessment of activity patterns associated with mild cognitive impairment. *Alzheimer's & Dementia,* 4(6), 395-405.

Herbert, L.E., Scherr, P.A., Bienias, J.L., Bennett, D.A., Evans, D.A. (2003). Alzheimer's disease in the U.S. population: Prevalence estimates using the 2000 census. *Archives of Neurology*, 60(8), 1119-1122.

Hux, M.J., O'Brien, B.J., Iskedjian, M., Goeree, R., Gagnon, M., Gauthier, S. (1998). Relation between severity of Alzheimer's disease and costs of caring. *Canadian Medical Association Journal*, 159(9), 457-465.

Intel Corporation (2003). Ubiquitous computing for cognitive decline: Findings from Intel's proactive health research. http://www.alz.org/national/documents/Intel_UbiquitousComputing.pdf. Accessed April 5, 2012.

Jimison, H.J., McKanna, J., Zitzelberger, T., Kaye, J. (2006). Monitoring computer interactions to detect early cognitive impariment in elders. 1st Distributed Diagnosis and Home Healthcare Conference, 75-78.

Kalpouzos G., Chetelat, G., Baron, J.C., Landeau, B., Mevel, K., Godeau, C., Barre, L., Constans, J.-M., Viader, F., Eustache, F., Desgranges, B. (2009). Voxel-based mapping of brain gray matter volume and glucose metabolism profiles in normal aging. *Neurobiology of Aging,* 30(1), 112-124.

Kaye, J.A., Maxwell, S.A., Mattek, N., Hayes, T.L., Dodge, H., Pavel, M., Jimison, H.B., Wild, K., Boise, L., Zitzelberger, T.A. (2011). Intelligent systems for assessing aging changes: Home-based, unobtrusive, and continuous assessment of aging. *Journal of Gerontology, Series B, Psychological Sciences and Social Sciences*, 66(Suppl. 1), i180-i190.

Kiecolt-Glaser, J.K., Marucha, P.T., Mercado, A.M., Malarkey, W.B., Glaser, R. (1995). Slowing of wound healing by psychological stress. Lancet, 346(8984), 1194-1196.

Kurz, A., Pohl, C., Ramsenthaler, M., Sorg, C. (2009). Cognitive rehabilitation in patients with mild cognitive impairment. *International Journal of Geriatric Psychiatry,* 24(2), 163-168.

Landau, R., Auslander, G.K., Werner, S., Shoval, N., Heinik, J. (2010). Families' and professional caregivers' views of using advanced technology to track people with dementia. *Qualitative Health Research,* 20(3), 409-419.

Larson, E.B., Shadien, M., Wang, L., McCormick, W.C., Bowen, J.D., Teri, L., Kukull, W.A. (2004). Survival after initial diagnosis of Alzheimer's disease. *Annals of Internal Medicine*, 140(7), 501-509.

Lopez, O.L., Kuller, L.H, Becker, J.T., Dulberg, C., Sweet, R.A., Gach, H.M., DeKosky, S.T. (2007). Incidence of dementia in mild cognitive impairment in the cardiovascular health study cognition study. *Archives of Neurology,* 64(3), 416-420.

LoPresti, E.F., Mihailidis, A., Kirsch, N. (2004). Assistive technology for cognitive rehabilitation: State of the art. *Neuropsychological Rehabilitation,* 14(1-2), 5-39.

Machulda, M.M., Ward, H.A., Borowski, B., Gunter, J.L., Cha, R.H., O'Brien, P.C., Petersen, R.C., Boeve, B.F., Knopman, D., Tang-Wai, D.F., Ivnik, R.J., Smith G.E., Tangalos, E.G., Jack Jr., C.R. (2003). Comparison of memory fMRI response among normal, MCI, and Alzheimer's patients. *Neurology*, 61(4), 500-506.

Martin, M., Clare, L., Altgassen, A.M., Cameron, M.H., Zehnder, F. (2011). Cognition-based interventions for healthy older people and people with mild cognitive impairment. *Cochrane Database of Systematic Reviews,* 19(1), CD006220.

Mayo Clinic (2010). Mild Cognitive Impairment. http://www.mayoclinic.com/health/mild-cognitive-impairment/DS00553. Accessed April 5, 2012.

McEvoy, L.K., Fennema-Notestine, C., Roddey J.C., Hagler, D.J., Holland, D., Karow, D.S., Pung, C.J., Brewer, J.B., Dale, A.M. (2009). Alzheimer's disease: Quantitative structural neuroimaging for detection and prediction of clinical and structural changes in mild cognitive impairment. *Radiology,* 251(1), 195-205.

Mihailidis, A., Boger, J.N., Craig, T., Hoey, J. (2008). The COACH prompting system to assist older adults with dementia through handwashing: An efficacy study. *BioMed Central Geriatrics*, 8(28).

Mitchell, S.L., Teno, J.M., Miller, S.C., Mor, V. (2005). A national study of the location of death for older persons with dementia. *Journal of the American Geriatrics Society,* 53(2), 299-305.

Morris, M., Lundell, J., Dishman, E. (2004). Catalyzing social interaction with ubiquitous computing: A needs assessment of elders coping with cognitive decline. *SIGCHI Conference, Extended Abstracts on Human Factors in Computing Systems*, 1151-1154.

Moskowitz, D.S., Young, S.N. (2006). Ecological momentary assessment: What it is and why it is a method of the future in clinical psychopharmacology. Journal of Psychiatry and Neuroscience, 31(1), 13-20.

Mubin, O., Shaihid, S., Mahmud, A. (2008). Walk 2 Win: Toward designing a mobile game for elderly's social engagement. 22nd British HCI Group Annual Conference on People and Computers: Culture, Creativity, Interaction -- Volume 2, 12-14.

Mundt, J.C., Ferber, K.L., Rizzo, M., Greist, J.H. (2001). Computer-automated dementia screening using a touch-tone telephone. Archives of International Medicine, 161(20), 2481-2487.

Mynatt, E., Rowan, J., Jacobs, A., Craighill, S. (2001). Digital family portraits: Supporting peace of mind for extended family members. *SIGCHI Conference on Human Factors in Computing Systems,* 333-340.

National Institutes of Health (2010). NIH consensus development conference statement on preventing Alzheimer's disease and cognitive decline. Bethesda, M.D.: U.S. Department of Health and Human Services. http://consensus.nih.gov/2010/docs/alz/ALZ_Final_Statement.pdf. Accessed April 5, 2012.

Oremus, M., Aguilar, S.C. (2011). A systematic review to assess the policy-making relevance of dementia cost-of-illness studies in the U.S. and Canada. *Pharmacoeconomics*, 29(2), 141-156.

Orwat, C., Graefe, A., Faulwasser, T. (2008). Towards pervasive computing in health care -- A literature review. *BioMed Central Medical Informatics and Decision Making,* 8(26).

Owen, A.M., Hampshire, A., Grahn, J.A., Stenton, R., Dajani, S., Burns, A.S., Howard, R.J., Ballard, C.G. (2010). Putting brain training to the test. *Nature,* 465(7299), 775-778.

Petersen, R.C., Roberts, R.O., Knopman, D.S., Boeve, B.F., Geda, Y.E., Ivnik, R.J., Smith, G.E., Jack, C.R., Jr. (2009). Mild cognitive impairment. *Archives of Neurology,* 66(12), 1447-1455.

Petersen, R.C., Roberts, R.O., Knopman, D.S., Geda, Y.E., Cha, R.H., Pankratz, V.S., Boeve, B.F., Tangalos, E.G., Ivnik, R.J., Rocca, W.A. (2010). Prevalence of mild cognitive impairment is higher in men. *Neurology*, 75(10), 889-897.

Plassman, B.L., Langa, K.M., Fisher, G.G., Heeringa, S.G., Weir, D.R., Ofstedal, M.B.,Wallace, R.B. (2007). Prevalence of dementia in the United States: The aging, demographics, and memory study. *Neuroepidemiology,* 29(1-2), 125-132.

Plassman, B.L., Langa, K.M., Fisher, G.G., Heeringa, S.G., Weir, D.R., Ofstedal, M.B.Wallace, R.B. (2008). Prevalence of cognitive impairment without dementia in the United States. *Annals of Internal Medicine,* 148(6), 427-434.

Rockwood, K. (2002). Vascular cognitive impairment and vascular dementia. *Journal of the Neurological Sciences,* 203, 23-27.

Rogers, W.A., Mynatt, E.D. (2003). How can technology contribute to the quality of life of older adults? In M.E. Mitchell, *The technology of humanity: Can technology contribute to the quality of life?,* 22-30. Chicago, IL: Illinois Institute of Technology.

Schubert, C.C., Boustani, M., Callahan, C.M., Perkins, A.J., Hui, S., Hendrie, H.C. (2008). Acute care utilization by dementia caregivers within urban primary care practices. Journal of General Internal Medicine, 23(11), 1736-1740

Seelye, A., Howieson, D., Wild, K., Sauceda, L., Kaye, J. (2009). Living well with MCI: Behavioral interventions for older adults with mild cognitive impairment. In R. Brougham, *New directions in aging research: Health and cognition,* 57-74. New York City, New York: Nova Biomedical Books.

Shaw, W.S., Patterson, T.L., Ziegler, M.G., Dimsdale, J.E., Semple, S.J., Grant, I. (1999). Accelerated risk of hypertensive blood pressure recordings among Alzheimer caregivers. Journal of Psychosomatic Research, 46(3), 215-227.

Shoval, N., Auslander, G., Cohen-Shalom, K., Isaacson, M., Landau, R., Heinik, J. (2010). What can we learn about the mobility of the elderly in the GPS era? *Journal of Transport Geography,* 18(5), 603-612.

Smith, G.E., Housen, P., Yaffe, K., Ruff, R., Kennison, R.F., Mahncke, H.W., Zelinski, E.M. (2009). A cognitive training program based on principles of brain plasticity: Results from the improvement in memory with plasticity-based adaptive cognitive training (IMPACT) study. *Journal of the American Geriatrics Society,* 57(4), 594-603.

Sörensen, S., Duberstein, P., Gill, D., Pinquart, M. (2006). Dementia care: Mental health effects, intervention strategies, and clinical implications. *Lancet,* 5(11), 961-973.

Suzuki, T., Murase, S. (2010). Influence of outdoor activity and indoor activity on cognition decline: Use of an infrared sensor to masure activity. *Telemedicine and e-Health,* 16(6), 686-690.

Tartaglia, M.C., Rosen, H.J., Miller, B.L. (2011). Neuroimaging in dementia. *Neurotherapeutics,* 8(1), 82-92.

Vitaliano, P.P., Scanlan, J.M., Zhang, J., Savage, M.V., Hirsch, I.B., Siegler, I. (2002). A path model of chronic stress, the metabolic syndrome and coronary heart disease. Psychosomatic Medicine, 64(3), 418-435.

Wolinsky, F.D., Unverzagt, F.W., Smith, D.M., Jones, R., Wright, E., Tennstedt, S.L. (2006). The effects of the ACTIVE cognitive training trial on clinically relevant declines in health-related quality of life. *Journal of Gerontology, Series B, Psychological Sciences and Social Sciences,* 61(5), S281-287.

Zelinski, E.M., Spina, L.M., Yaffe, K., Ruff, R., Kennison, R.F., Mahncke, H.W., Smith, G.E. (2011). Improvement in memory with plasticity-based adaptive cognitive training: Results of the 3-month follow-up. *Journal of the American Geriatrics Society,* 59(2), 258-265.

CHAPTER 5: SENSORY IMPAIRMENTS

5.1. Definition of Sensory Impairments

Sensory impairment is a reduction in an individual's ability to process sensory stimuli. This includes visual impairment, which is a reduction in visual abilities that cannot be corrected to normal levels, and hearing impairment, which is a reduction in hearing ability relative to age-appropriate norms. Both visual and hearing impairments are common among older adults (Centers for Disease Control and Prevention, 2011; Yueh et al., 2003).

Although many factors can cause visual impairment, age-related macular degeneration (AMD), cataracts, and glaucoma are the most common causes (Centers for Disease Control and Prevention, 2011). Visual impairments are also common among those with autism, and can result from complications related to high blood pressure, diabetes, and other conditions, adding complexity to the patient profile and treatment plan. Treatment of visual impairment varies widely, ranging from simple prescription glasses to lens-replacement surgery. Despite the availability of effective treatment for some of the underlying causes of visual impairment, other causes are less responsive to treatment and can result in permanent impairments.

Hearing loss results from a number of conditions that impede the ear's ability to sense and process sound. There are three forms of hearing loss: conductive, sensorineural, and mixed conductive and sensorineural. Conductive hearing loss is caused by mechanical abnormalities such as a perforated eardrum, and is often treated surgically. However, more than 90 percent of hearing loss is sensorineural, which is permanent, often related to age and sometimes diseases such as diabetes. Sensorineural hearing loss involves damage to or deterioration of the acoustic nerve or the hair cells of the inner ear that transmit acoustic signals to the brain and enable the perception of sound. Since there are no treatments for this damage, sensorineural hearing loss is often treated with devices such as hearing aids, which aim to compensate for rather than reverse hearing loss. However, cochlear and middle ear implants may be appropriate in cases where hearing aids are not suitable (Yueh et al., 2003). Mixed hearing loss involves a combination of conductive and sensorineural loss.

Although people with mild visual and hearing loss can often function at normal levels, moderate to severe loss or dual sensory impairments can have a profound impact on the ability of older adults or persons with disabilities to live independently in the community (Saunders and Echt, 2007). These individuals can face a number of specific problems associated their sensory impairments, including difficulties manipulating the controls on traditional hearing aids; anatomical features that preclude hearing aid use or make these devices an unappealing treatment option; hearing loss that is not improved with hearing aids; reduced ability to use telephones, computer screens, or other routine communication technologies; limitations in the ability to engage in household management and reduced capacity to safely navigate the physical environment. A number of technologies are currently on the market and under development that aim to address these and other issues associated with sensory impairments.

5.2. Prevalence of Senior Impairments

Hearing and visual impairments are common among older adults and the prevalence increases with age (Prevent Blindness America, 2008).

Visual Impairments

The most common causes of loss of vision among older adults are age-related macular degeneration (AMD), cataracts, and glaucoma. AMD causes loss of sharp, focused central vision, making it difficult or impossible to drive, read, or recognize faces. While AMD affects only 2 percent of adults aged 50 to 69, its prevalence increases to 30 percent among people age 75 and over, highlighting increases in this condition with advancing age (National Eye Institute, 2009a). Cataracts cloud the lens of the eye and obscure vision. Although cataracts can develop in adults as young as 40, they are much more prevalent in older adults (National Eye Institute, 2009b). One study reported that 44 percent of individuals over the age of 70 have cataracts, and by the age of 80 half of Americans either have a cataract or have had cataract surgery (Congdon et al., 2004). Glaucoma is typically associated with increased pressure inside the eye that results in a reduction in peripheral vision and, if left untreated, irreversible blindness. Under- and delayed diagnosis of glaucoma are serious problems because patients experience few symptoms until significant damage to the optic nerve creates noticeable blind spots. According to a 2006-2008 survey of 15 states, between 6.8 and 12.3 percent of adults over 65 report suffering from glaucoma and the rate is projected to rise as diabetes incidence increases (Centers for Disease Control and Prevention, 2011).

Hearing Impairments

The prevalence of hearing impairment increases markedly with age. Between 25 and 40 percent of adults over age 65, 40 to 60 percent of adults over age 75, and more than 80 percent of adults over age 85 experience measurable reductions in hearing. Despite its prevalence, hearing impairment is under-diagnosed and therefore undertreated. Only 9 percent of primary care physicians offer hearing tests to patients age 65 years and older, suggesting that screening is not a routine feature of care for this population. Further, only 25 percent of patients with diagnosed hearing impairment use amplification devices such as hearing aids (Yueh et al., 2003), suggesting that diagnosis does not necessarily result in treatment. Low levels of hearing aid use may be related to a number of factors, including patients' perceptions regarding the severity of the hearing impairment, the expense associated with purchasing these devices, lack of awareness regarding the availability of this treatment option, and reluctance to use assistive devices because of perceived stigma.

Dual Sensory Impairments

Concurrent visual and hearing impairments are common among older adults in the United States. Data collected from a survey conducted by the National Center for Health Statistics suggest that concurrent visual and hearing impairments affect 7 percent of adults age 65 to 79 and 17 percent of adults over age 80 (Caban et al., 2005). One study suggests that the presence of a visual impairment can be predictive of a hearing impairment in adults over 80, an association that could improve diagnosis and treatment opportunities for both conditions (Schneck et al., 2011).

5.3. Costs and Burdens Associated with Sensory Impairments

Visual impairments and blindness are estimated to cost $35 billion annually in direct medical costs and lost productivity, with these impairments alone accounting for $11 billion in nursing-home costs (Rein et al., 2006). Among Medicare beneficiaries with glaucoma, costs increase as visual capacity decreases. Compared to adults with glaucoma but no vision loss, annual costs associated with glaucoma are $5,005 higher for patients with moderate vision loss, $7,155 higher for those with severe vision loss, and $10,513 higher for those with blindness (Bramley et al., 2008). Cataracts are associated with particularly high health-care costs: this condition accounts for approximately 60 percent of all Medicare expenditures related to vision problems (Congdon et al., 2004).

Hearing impairments are estimated to account for between $154 billion and $186 billion in health-care expenditures each year. Medical equipment such as hearing aids can be costly, as can treatment for secondary conditions such as ear infections, which are common among those with hearing impairments. Hearing-impaired individuals have been shown to utilize more health-care services (e.g., outpatient visits) than do those without these impairments (Green and Pope, 2001).

In addition to the direct medical costs and increased service utilization linked to visual and hearing impairments, these conditions are also associated with considerable burdens to both patients and caregivers. Sensory impairments can contribute to loss of independence by inhibiting affected individuals from performing routine tasks that are required for self-care, home maintenance, and engaging in basic communication (Caban et al., 2005). Visual impairments can create challenges in preparing meals and shopping. Hearing loss also inhibits activities such as using the telephone to attend to household responsibilities and engaging with friends and family (Brennan, Horowitz, and Su, 2005). Hearing loss makes it difficult for people of all ages to communicate with their social networks, thereby enhancing the risk of social isolation. Indeed, one study of older adults showed that those with moderate to severe hearing loss were eight times more likely to report difficulties with communication than were those without hearing loss (Dalton et al., 2003). Social isolation, in turn, is a risk factor for depression, suggesting a pathway linking sensory impairments and this condition that is supported by data from a national survey showing that individuals with sensory impairments were more likely to report symptoms of depression than were those without these impairments (Capella-McDonnall, 2005). Both depression and social isolation are described in greater detail in Chapter 6 of this report.

For adults with visual impairments, mobility-related tasks such as climbing stairs are often adversely impacted, often with serious consequences. As discussed in Chapter 1 of this report, visual impairment is a major risk factor for falls. Older individuals with vision problems are nearly twice as likely to have experienced a fall within the past 12 months and 1.7 times more likely to have experienced a broken hip resulting from a fall than are those without vision problems (Crews and Campbell, 2004). Further, poor vision is a leading reason for older adults to stop driving, which in itself contributes to social isolation and increased dependence on family and friends.

Finally, older adults with sensory impairments are more likely to have comorbid conditions such as hypertension and heart disease than are their counterparts without these impairments. Controlling for age, older adults with dual sensory impairments are 2.4 times more likely to report heart disease and 3.6 times more likely to have had a stroke than are those without vision or hearing impairments. The same pattern emerges with other conditions (e.g., depression, arthritis, diabetes), wherein the more severe the sensory impairment, the greater the comorbidity. Although it may be difficult to distinguish cause and effect, it is clear that sensory impairments are strongly associated with older adults' health and activity patterns in a manner that results in diminished quality of life among affected individuals (Crews and Campbell, 2004).

5.4. Available Sensory Impairment Technology Solutions and Evidence of Their Benefits

A number of technologies are available to address the needs of individuals with visual and hearing impairments. These technologies can generally be classified into four categories: intervention options, auxiliary and adaptive aids, technologies that address household responsibilities, and those addressing navigation.

Intervention Options

Hearing aids, middle-ear implants, cochlear implants, and electric acoustic stimulation are technologies that address hearing impairments in people of all ages (Sprinzl and Riechelmann, 2010). In most cases, the nature and severity of the hearing impairment dictate the treatment strategy, with hearing aids being the most common treatment for hearing loss. Hearing aids, which are available in both analog and digital form, amplify sound. Early intervention with hearing aids on some types of hearing loss has been shown to halt or reverse hearing impairment in older adults and, among those with mild-to-severe hearing impairment, they are considered to be the most effective treatment (Yueh et al., 2003). Hearing aids vary in size, cost, features, and mode of use. The largest hearing aid consists of a case containing the amplifier and is used in conjunction with an in-ear component. For the most part, this type of hearing aid has been replaced by more compact devices that are worn behind the ear, in the ear, or in the ear canal (Dillon, 2001). The smallest of these devices is worn completely in the ear canal and is almost invisible from the outside. In general, there is an inverse relationship between hearing aid size and cost.

Active middle ear implants (AMEI) are implantable alternatives to hearing aids in which all components, including the microphone and battery, are implanted under the skin. These devices can be suitable alternatives for older adults who have difficulty manipulating traditional hearing aids' controls or who have collapsed ear canals that cannot accommodate hearing aids. Thus far, testing has focused on adults of all ages and has not specifically targeted older populations. Adults age 28 to 86 have reported improved hearing, speech recognition, and listening ease, as well as satisfaction with these devices (Sprinzl and Riechelmann, 2010).

Older adults with severe hearing loss might opt for a cochlear implant if they are determined to be a good candidate for this procedure. Cochlear implants are small, electronic devices consisting of an external portion that sits behind the ear and a second portion that is surgically placed under the skin (National Institute on Deafness and Other Communication Disorders, 2011). Unlike hearing aids and AMEI, cochlear implants are not amplifiers; rather, they act as prosthetic substitutes for the ear itself, providing electric stimulation directly to the auditory nerve. Several studies have documented improvements in quality of life associated with cochlear implants (Sprinzl and Riechelmann, 2010), and others have shown them to be a cost-effective approach to addressing advanced sensorineural hearing impairment (Yueh et al., 2003).

Electric acoustic stimulation (EAS), which involves the use of a hearing aid and a cochlear implant together in the same ear, can also be suitable for older adults who receive limited benefit from hearing aids or for whom hearing aids are otherwise not suitable. With EAS intervention, the hearing aid amplifies low-frequency sounds while the cochlear implant addresses middle and high frequencies. Although this is a relatively new technology, studies have shown improved hearing with EAS relative to hearing aids alone. Although more research is needed among older adults, this technology appears promising (Sprinzl and Riechelmann, 2010).

Currently, non-surgical, vision-related interventions are limited to lenses and magnification devices. A number of sophisticated surgical options exist that augment or partially restore sight, but these devices are in earlier phases of testing and therefore they are described in the section on technologies under development. For non-surgical interventions, technological advances have improved corrective eyewear by increasing magnifying power while decreasing glare, lens weight, and lens thickness, which improves both comfort and cosmetics for users. High-powered spectacle lenses, hand-held magnifiers with LED light bulbs, and head-worn magnifiers can be prescribed to amplify vision to enable people to read and perform other tasks that require near vision.

These devices, combined with bright lighting in the home, can significantly enhance older adults' vision. However, as the magnification power increases, the visual field narrows, making these devices unsuitable for driving and other routine daily activities that require distance vision (Woo, 2008).

A number of technologies target individuals with dual sensory impairments. One such product involves a hearing aid that is built into eyeglass frames. Although this approach to dealing with dual impairment was popular prior to the development of modern, compact hearing aids, it has recently experienced renewed appeal among older adults. Another glasses-based technology for people with dual sensory impairments features a series of microphones that have directional sensitivity, and intensify sounds coming from the front of the glasses while selectively filtering out surrounding noise. Such devices have more than twice the sensitivity of a standard hearing aid, and feature a button that is incorporated into the glasses frame that allows users to modify the sound level (AARP International, 2007). An additional benefit of eyeglass hearing aids is that they provide hearing assistance in a subtle manner, an important consideration for users who might otherwise refrain from using aids due to self-consciousness or perceived stigma.

Auxiliary Adaptive Aids

Auxiliary aids and adaptive equipment are devices that aim to assist individuals with sensory impairments by using technology to compensate for sensory loss. For instance, older adults with visual impairment can benefit from tools such as talking watches and phones as well as electronic devices with large buttons and easy-to-read displays. It has been demonstrated that these "low-tech" adaptive devices improve quality of life, foster independence, and contribute to injury prevention among older adults (Mann et al., 1999). Telephone amplifying devices are also available for people with hearing impairments. In addition to featuring extra-large buttons and a loud ringer, these devices can be compatible with hearing aids and set up to use a visual ring indicator. Similarly, many cell phones and traditional telephones now include features that make them compatible with hearing aids. Alerting devices such as doorbells and smoke alarms can also use visual and vibration, rather than audio cues (Nichols, 2006).

A number of technologies are available that facilitate computer use among people with visual and hearing impairments. For instance, screen magnifiers enlarge text and images on a computer screen and are among the most common adaptive technologies for visually impaired people. There is also software that inverts colors to increase the contrast and readability of screen displays. Tabletop and hand-held closed circuit TV enlarger (CCTV) technologies that magnify pictures and documents are another option for increasing readability. Portable video magnifying devices are available, as are wearable CCTV devices that allow both close and distant viewing through a unit worn on the user's head. Other devices feature speech synthesizers that convert text into spoken words (e.g., Intel Reader). Internet browser software can also be modified for the visually impaired. These browsers feature high-contrast modes and increased font sizes and can frequently incorporate screen reader features that convert text into speech. There are also applications designed for cellular phones that convert text into speech, provide screen magnification to allow visually impaired, including those who are completely blind, users to manipulate many features of their smart phones such as instant messaging, e-mail, calendar, and settings. Personal listening systems and amplifiers also cater to people with hearing impairments. These devices consist of a microphone attached to a receiver that the user controls with a handset. Relatively inexpensive and easy to use, these hand-held, battery-operated devices can be useful for one-on-one conversations or activities that require sound, such as watching television (Nichols, 2006).

Technologies Addressing Household Responsibilities

Sensory impairments can have a significant impact on adults' ability to maintain their households, making these impairments meaningful risk factors for loss of independence (Raina, Wong, and Massfeller, 2004). A number of technologies aim to improve the ability of people with visual impairments to engage in routine household activities, thereby helping to preserve independence. Bar-code readers are one example of this class of technologies. Using standard product bar codes, these systems help visually impaired individuals identify packaged items such as food and cleaning products. Similar technologies read information on prescription medication containers, thereby helping the user manage medications. Technology-enhanced items such as electronic liquid-level indicators can help with meal preparation and assist users maintain their independence by compensating for diminished sensory capacity.

Technologies Addressing Navigation

Reduced ability to navigate one's environment effectively is a strong risk factor for loss of independence. Visual impairment inhibits mobility and navigation and can therefore lead to loss of independence. Technologies that assist with navigation, such as GPS units and technology-enhanced supports like intelligent walkers and canes, can help older adults with visual impairments retain functions that are critical for independent living. GPS systems designed for people with visual impairments have a voice-over feature that allows users to navigate the menus of the device, input their desired destination, select a navigation mode (such as walking), and start the navigation. These devices can support the user's orientation relative to their surroundings, thereby providing a greater sense of security with navigation and mobility (National Federation of the Blind, 2010). The Veterans Affairs Personal Adaptive Mobility Aid (VA-PAMAID) is an intelligent walker that identifies features such as junctions and corridors and conveys this information to the user as a voice message (Nelson et al., 2004). One cane technology emits signals similar to radar and features real-time sensing and feedback. This device detects both the size and distance of surrounding obstacles and conveys this information to the user with vibrating buttons in the cane's handle. The cane can also detect items that are at head height, an advancement over traditional canes that detect only ground-level objects in the user's path.

5.5. Sensory Impairment Technologies Currently Under Development

A number of innovative technologies are under development to address challenges associated with sensory impairment. One class of new technologies involves intervention in the form of new, surgically implanted devices that may reduce or reverse impairment for both visually and hearing-impaired individuals. These approaches involve replacement of the deficient human structure underlying the impairment, and include an implantable telescope, an artificial retina, and an artificial cochlea (Rau et al., 2010). In 2010, the U.S. Food and Drug Administration approved the use of implantable telescopes for severe age-related macular degeneration. A miniature telescope is implanted into one eye to magnify the central field of vision 2.2 to 2.7 times, while the other eye is used for peripheral vision, typically with the aid of prescription lenses (Food and Drug Administration, 2010). A recent study found the implantable telescope improved both visual functioning as well as patients' quality of life (Singer et al., 2012). The artificial retina is another means of targeting severe visual impairment in cases where macular degeneration and other diseases have permanently damaged retinal cells. An artificial retina involves coordinated action of several devices: an eyeglass-mounted camera to record the user's surroundings, a belt-mounted device to convert the camera images into electrical signals, and a retinal implant that receives these electrical signals and transmits them across undamaged cells in the eye. Thus far, this technology remains in the testing and improvement phase--only 31 patients have received retinal implants since 2002, with several of them experiencing modest visual improvements (Artificial Retina Project, 2009). Two sites in the U.S. are currently experimenting with cortical prosthesis, in which electrodes are implanted into the visual cortex of the brain to stimulate the neurons associated with sight. These devices bypass the retina, optic nerve, and other parts of the eye that might be damaged by disease. Currently, people with damage to these areas can maintain their existing vision but have no therapeutic options to restore vision, meaning this technology could provide immense benefit. The projects gained FDA approval in 2007 and are currently testing the devices with human volunteers (Ong and da Cruz, 2012).

Recent advances in engineering are allowing researchers to experiment with a "bio-inspired" artificial cochlea that approximates not only the function but also the physical structure of the cochlea. Current designs focus on replacing the cochlear hair cells and the basilar membrane, which anchors the hairs, both of which are crucial for hearing. One design tested the materials, the physical design of the membrane, and whether electrical transmissions successfully approximate hearing (Kim et al., 2011). Another tested the artificial membranes and hair cells in guinea pigs and found that they were successful in stimulating the rest of the ear and transmitting sound to the brain. However, the signal is not yet powerful enough to generate a response in the brain (Inaoka et al., 2011). In the future, advances in these technologies could potentially replace damaged structures in the cochlea and restore hearing to individuals of any age.

Other emerging devices target visual and hearing impairments using non-surgical means. For example, a cell phone is under development that will allow hearing-impaired individuals to communicate with 911 call centers using a module that converts text to speech. Other innovative technologies address mobility challenges and are particularly relevant for older adults with visual impairments. For example, an innovative device aimed at facilitating mobility utilizes a shoe-mounted sensor system to aid in navigation. An advantage of this device is that it is hands-free, a feature that contrasts with traditional hand-held canes (Zhang et al., 2010).

Other new technologies offer improvements to currently available wearable and surgical options that address sensory impairments. One example of these applications involves directional microphones that improve sound localization. Patients often report discontinuing their use of traditional hearing aids because they magnify the volume of both the speech "signal" and background "noise," but do not aid users in distinguishing signal from noise. Directional hearing aids use multiple microphones, which minimize noise, enhance the speech signal, and are effective for individuals with mild to moderate hearing impairments. Improvements to these devices are also beginning to generate favorable effects for patients with severe hearing impairment and for whom hearing aids are not fully effective (Gnewikow et al., 2009).

5.6. Experiences of Other Countries with Sensory Impairment Technologies

The Hearing at Home project is a European Union (EU) initiative that aims to develop individualized solutions for people with hearing impairment. The project addresses a variety of challenges in the home and is designing a technology platform to integrate television, phone, and computer use (Hearing at Home, 2010). Similarly, a Danish hearing aid manufacturer recently developed a wireless hearing aid that connects to several special home appliances such as special phones, cell phones, televisions, and personal computers. This integration allows transmitting the audio signal from the appliance directly to the hearing aids wirelessly and temporarily turning off the hearing aid microphone to eliminate ambient noise and enhance the listening experience.

Based in Sweden, the Office of Research in Clinical Amplification (ORCA) is a research organization focusing on the efficacy of existing amplification devices as well as prototype hearing aids (Office of Research in Clinical Amplification Europe, 2010). ORCA projects have focused on hearing thresholds at high frequencies, hearing aid noise reduction and amplification, as well as evaluation of new technologies.

The Secure and Safe Mobility Network (SESAMONET) is under development by the European Commission’s Joint Research Centre to assist visually impaired people with navigation. This system uses microchips installed in the ground to send messages to a smart phone, which in turn relays this information as voice directions to an earpiece worn by the user. Although promising, this device is a prototype the utility of which would be limited to areas in which the microchips are installed (European Commission Joint Research Centre, 2007).

In Germany and the United Kingdom, researchers are developing retinal implant technology that aims to restore sight. One technology is similar to artificial retinal implants being developed in the U.S. for implantation directly onto the retinal surface. Another is a cybernetic device that uses both glasses and an eye implant; the glasses contain a camera and video processor that send information to a receiver that is surgically implanted in the eye. Although continued testing will be necessary to demonstrating the safety and efficacy of this technology, preliminary results of a prototype have shown promise (Ong and da Cruz, 2012). Similarly, Bionic Vision Australia is a cooperative effort involving several Australian research organizations the goal of which is to create the first bionic eye that will allow people with specific forms of severe visual impairment to regain some of their vision. This technology also uses a combination of glasses and a microchip implanted in the eye and is still in development (Bionic Vision Australia, 2010). These technologies are similar in principle to the artificial retina technology under development in the U.S. that is mentioned in Section 5.5.

References

AARP International (2007). Netherlands: Dutch Unveil 'Varibel' -- The Eyeglasses That Hear. http://www.aarpinternational.org/agingadvances_sub/agingadvances_sub_show.htm?doc_id=553940. Accessed April 3, 2012.

Artificial Retina Project (2009). Overview of the Artificial Retina Project. Washington, D.C.: U.S. Department of Energy. http://artificialretina.energy.gov. Accessed April 3, 2012.

Bionic Vision Australia (2010). Bionic Vision Australia. http://bionicvision.org.au/. Accessed April 3, 2012.

Bogardus, S., Yueh, B., Shekelle, P. (2003). Screening and management of adult hearing loss in primary care. *Journal of American Medical Association,* 289(15), 1986-1990.

Bramley, T., Peeples, P., Walt, J.G., Juhasz, m., Hansen, J.E. (2008). Impact of vision loss on costs and outcomes in Medicare beneficiaries with Glaucoma. *Archives of Opthalmology,* 126(6), 849-856.

Brennan, M., Horowitz, A., Su, Y.P. (2005). Dual sensory loss and its impact on everyday competence. *The Gerontologist,* 45(3), 337-346.

Caban, A.J., Lee, D.J., Gomez-Marin, O., Lam, B.L., Zheng, D. (2005). Prevalence of concurrent hearing and visual impairment in U.S. adults; The national health interview survey. *American Journal of Public Health,* 95(11), 1940-1942.

Capella-McDonnall, M.E.. (2005). The effects of single and dual sensory loss on symptoms of depression in the elderly. *Journal of Geriatric Psychiatry,* 20(9), 855-861.

Centers for Disease Control and Prevention (2011). The state of vision, aging, and public health in America. Atlanta, G.A.; U.S. Department of Health and Human Services. http://www.cdc.gov/visionhealth/pdf/vision_brief.pdf. Accessed April 3, 2012.

Congdon, N., Vingerling, J.R., Klein, B.E., West, S., Friedman, D.S., Kempen, J., O'Colmain, B., Wu, S.Y., Taylor, H.R. (2004). Prevalence of cataract and pseudophakia/aphakia among adults in the United States. Archives of Ophthalmology, 122(4), 487-494.

Crews, J.E., Campbell, V.A. (2004). Vision impairment and hearing loss among community-dwelling older Americans: Implications for health and functioning. *American Journal of Public Health,* 94(5), 823-829.

Dalton, D.S., Cruichshanks, K.J., Klein, B.E., Klein, R., Wiley, T.L., Nondahl, D.M. (2003). The impact of hearing loss on quality of life in older adults. *The Gerontologist,* 43(5), 661-668.

Dillon, H. (2001). *Hearing aids*. New York, New York: Boomerang Press.

European Commission Joint Research Centre. (2007). Secure and safe mobility network (SESAMONET). http://ec.europa.eu/dgs/jrc/index.cfm?id=4210. Accessed January 25, 2012.

Friedman, D.S., O'Colmain, B.J., Muñoz, B., Tomany, S.C., McCarty, C., de Jong, P.T., Nemesure, B., Mitchell, P., Kempen, J. (2004). Prevalence of age-related macular degeneration in the United States. *Archives of Ophthalmology,* 122(4), 564-572.

Food and Drug Administration (2010). FDA approves first implantable miniature telescope to improve sight of AMD patients. Silver Spring, M.D.: U.S. Department of Health and Human Services. http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm218066.htm. Accessed April 3, 2012.

Glaucoma Foundation (2011). Fast facts on glaucoma. http://www.glaucomafoundation.org/news_detail.php?id=180. Accessed April 3, 2012.

Gnewikow, D., Ricketts, T., Bratt, G.W., Mutchler, L.C. (2009). Real-world benefit from directional microphone hearing aids. *Journal of Rehabilitation Research and Development*, 46(5), 603-618.

Green, C., Pope, C. (2001). Effects of hearing impairment on use of health services among the elderly. *Journal of Aging and Health,* 13(3), 315-328.

Hearing at Home (2010). Hearing at Home. http://www.hearing-at-home.eu/. Accessed April 3, 2012.

Inaoka, T., Shintaku, H., Nakagawa, T., Kawano, S., Ogita, H., Sakamoto, T. (2011). Piezoelectric materials mimic the function of the cochlear sensory epithelium. *Proceedings of the National Academy of Sciences*, 108(45), 18390-18395.

Kim, W.D., Lee, J.H., Choi, H.S., Hur, S., Park, J.S. (2011). Design of a totally implantable artificial cochlea mimicking the human hearing mechanism. *Springer Proceedings in Physics,* 138, 67-75.

Mann, W.C., Ottenbacher, K.J., Fraas, L., Tomita, M., Granger, C.V. (1999). Effectiveness of assistive technology and environmental interventions in maintaining independence and reducing home care costs for the frail elderly*. Archives of Family Medicine,* 8(3), 210-217.

National Eye Institute (2009a). Facts about age-related macular degeneration. Bethesda, M.D.: U.S. Department of Health and Human Services. http://www.nei.nih.gov/health/maculardegen/armd_facts.asp. Accessed April 3, 2012.

National Eye Institute (2009b). Facts about cataract. Bethesda, M.D.: U.S. Department of Health and Human Services. http://www.nei.nih.gov/health/cataract/cataract_facts.asp. Accessed April 3, 2012.

National Federation for the Blind. (2010). Products and technology. http://www.nfb.org/nfb/Products_and_Technology.asp. Accessed April 3, 2012.

National Institute on Deafness and Other Communication Disorders (2011). Cochlear implants. Bethesda, M.D.: U.S. Department of Health and Human Services. http://www.nidcd.nih.gov/health/hearing/pages/coch.aspx. Accessed April 3, 2012.

Nelson, A., Powell-Cope, G., Gavin-Dreschnack, D., Quigley, P., Bulat, T., Baptiste, A.S., Applegarth, S., Friedman, Y. (2004). Technology to promote safe mobility in the elderly. The *Nursing Clinics of North America,* 39(3), 649-671.

Nichols, A.D. (2006). Hearing loss: perceptions and solutions: Hearing loss can be dealt with effectively to improve a resident's quality of life. Long-Term Living. http://www.ltlmagazine.com/article/hearing-loss-perceptions-and-solutions. Accessed April 3, 2012.

Ong, J.M., da Cruz, L. (2012). The bionic eye: A review. Clinical and Experimental Ophthalmology, 40(1), 6-17.

ORCA Europe (2010). ORCA Europe. http://www.orca-eu.info/. Accessed April 3, 2012.

Prevent Blindness America. (2008). Vision Problems in the U.S.: Prevalence of Adult Vision Impairment and Age-Related Eye Disease in America. Bethesda, MD: National Institutes of Health. http://www.preventblindness.net/site/DocServer/VPUS_2008_update.pdf. Accessed May 28, 2012.

Raina, P., Wong, M., Massfeller, H. (2004). The relationship between sensory impairment and functional independence among elderly. *BioMed Central Geriatrics,* 4(3).

Rau, T.S., Hussong, A., Leinung, M., Lenarz, T., Majdani, O. (2010). Automated insertion of preformed cochlear implant electrodes: Evaluation of curling behaviour and insertion forces on an artificial cochlear model. *International Journal of Computer Assisted Radiology and Surgery,* 5(2), 173-181.

Rein, D.B., Zhang, P., Wirth, K.E, Lee, P.P., Hoerger, T., Nancy, M., Klein, K., Tielsch, J. Vijan, S., Saaddine, J. (2006). The economic burden of major adult visual disorders in the United States. *Archives of Ophthalmology,* 124(12), 1754-1760.

Saunders, G.H., Echt, K.V. (2007). An overview of dual sensory impairment in older adults: Persepctives for rehabilitation. *Trends in Amplification,* 11(4), 243-258.

Schneck, M.E., Lott, L.A., Haegerstrom-Portnoy, G., Brabyn, J.A. (2011). Association between hearing and vision impairments in older adults. *Ophthalmic and Physiological Optics*, 32(1), 45-52.

Singer, M.A., Amir, N., Herro, A., Porbandarwalla, S.S., Pollard, J. (2012). Improving quality of life in patients with end-stage age-related macular degeneration: Focus on miniature ocular implants. *Clinical Ophthalmology*, 6, 33-39.

Sprinzl, G.M., Riechelmann, H. (2010). Current trends in treating hearing loss in elderly people: A review of the technology and treatment options -- A mini-review. *Gerontology,* 56(3), 351-358.

Tucci, D.L., Merson, M.H., Wilson, B.S. (2010). A summary of the literature on global hearing impairment: Current status and priorities for action. *Otology & Neurotology*, 31(1), 31-41.

Woo, S. (2008). Vision impairment assessment and assistive technologies. In M. Alwan and R. Felder, *Aging Medicine, Eldercare Technology for Clinical Practitioners*, 121-142. Totowa, New Jersey: Humana Press.

Yueh, B., Shapiro, N., MacLean, C.H., Shekelle, P.G. (2003). Screening and management of adult hearing loss in primary care: Scientific review. *Journal of American Medical Association,* 289(15), 1976-1985.

Zhang, J., Lip, C., Ong, S., Nee, A. (2010). A multiple sensor-based shoe-mounted user interface designed for navigation systems for the visually impaired. 5th Annual Wireless Internet Conference (WICON), 1-8.

CHAPTER 6: DEPRESSION

6.1. Definition of Depression

Clinical depression (referred to as 'depression' throughout this chapter) is a mood disorder defined by feelings such as sadness, loss, anger, or frustration that interfere with everyday life for an extended period of time. There are several types of depression, the most common of which is major depression. Major depression may consist of a combination of symptoms, including depressed mood, reduced interest in activities, loss of energy, difficulty concentrating, and suicidal thoughts or intentions (American Psychiatric Association, 2000). Major depression is emotionally and physically disabling, and often recurs throughout a person's life (Bruce et al., 2002).

Although many older adults experience depressive symptoms, most do not meet diagnostic criteria for major depression. Dysthymic disorder is a milder, chronic form of depression. This disorder is characterized by the presence of two or more of the following symptoms for at least two years: under or over-eating, sleep disturbances, fatigue, low self-esteem, difficulty with concentration or decision-making, and feelings of hopelessness (American Psychiatric Association, 2000). While dysthymic disorder is not as disabling as major depression, its symptoms are sufficiently severe to impede normal functioning (National Institute of Mental Health, 2011). Qualified minor, subsyndromal, and subthreshold depression are terms used to describe people who do not have major depression, but who exhibit symptoms that impede their ability to function normally (Lyness et al., 2006).

Social isolation occurs when an individual has limited contact with others, and perceives that level of contact as inadequate (Findley, 2003). Social isolation is both a risk factor for and a result of depression. This bi-directional relationship highlights the importance of addressing social isolation in both the prevention and treatment of depression. Examining the quality of social networks, the negative feelings that arise when interactions decrease, and the number and frequency of social interactions can be an important feature of broader strategies aimed at addressing depression (Biordi and Nicholson, 2009).

Although depression affects people of all ages, there are unique and complex factors that contribute to depression in older adults (MedlinePlus, 2010). For example, decrements in psychological health and economic status often accompany aging, and both can contribute to depression (Victor et al., 2002). Other examples of factors that contribute to depression include retirement and bereavement, both of which occur with increasing frequency at older ages. When adults enter retirement, their social networks are disrupted, and they also tend to engage more frequently in solitary activities (Chapman and Perry, 2008). Bereavement, particularly the loss of a spouse or partner, often results in drastic disruptions to social networks. While friends and family generally support an individual immediately following a spouse or partner's death, this support typically decreases over time (Breen and O'Connor, 2011). Further, age-associated disability can increase risk of depression when physical limitations result in changes in activities that result in a loss of personal and social identity or independence. These losses can result in a sense of hopelessness that may ultimately lead to withdrawal from social networks (Arnadottir et al., 2011). Physiological and psychological illnesses are often closely intertwined in aging populations--depression can be both a consequence of and complicating factor in chronic disease and can worsen the health outcomes of those it affects (Moussavi et al., 2007). Finally, older adults often experience difficulties accessing mental-health care and other services because they often stop driving, are unable to secure reliable transportation, or are unable to leave their homes to access services due to physical limitations (Prinz, Cramer, and Englund, 2008).

A number of technologies address problems stemming from the complex interplay of depression, physical health, and social isolation. These technologies target specific depression-related problems, including challenges associated with effective diagnosis; lack of access to mental-health professionals and services that results in inadequate treatment; perceived stigma on the part of affected individuals; loss of motivation and sense of purpose; and social isolation. In addition to these problems, the families and friends of depressed individuals often experience their own distinct depression-related burdens as a result of the physical and psychological challenges associated with caring for loved ones with depression. Technologies addressing these problems seek to reduce depressive symptoms, improve access to care among affected persons, and improve social connectedness. Some of these are used in provider settings, some are used by patients at home, and still others work by connecting patients and providers. In some cases, these technologies may not only address problems resulting directly from depression itself, but also from health conditions that occur in tandem with depression.

6.2. Prevalence of Depression

Depression is a growing concern among older adults and people with disabilities (National Institute of Mental Health, 2011). Although the occurrence of depression among these populations varies based on residential setting, degree of social isolation, and level of disability, it has been estimated that major depression occurs in 1 to 4 percent of the community-dwelling population ages 60 and older (Centers for Disease Control and Prevention, 2009). While estimates vary, approximately 13 to 25 percent of nursing-home residents have a diagnosis of depression (Watson et al., 2009). Consistent with this concept are data from one study showing that social isolation, which can be a risk factor for depression, is present in as many as 35 percent of older adults in assisted-living facilities (Greaves and Farbus, 2006).

One report showed that, among older adults, less than 20 percent of all depression cases are actually diagnosed by a health-care professional (Cole and Dendukuri, 2003). This finding suggests that opportunities to initiate treatment of depression in older adults are not realized in a majority of cases. Further, it has been shown that less than 50 percent of older adults who are diagnosed with depression actually receive anti-depressant treatment, even in long-term care facilities where the prevalence is relatively high (Katon and Guico-Pabia, 2011; Gaboda et al., 2011). This suggests that a diagnosis of depression is frequently not sufficient for initiation of treatment. Moreover, minor and subsyndromal depression symptoms among older adults are often missed because they are viewed as part of normal aging, and therefore remain undiagnosed (Lyness et al., 2006). Additional challenges contributing to under-diagnosis of depression include minimizing the importance of psychological symptoms on the part of both patients and providers, attributing symptoms to physical causes, and a perception of stigma on the part of older adults that inhibits them from seeking treatment (Bruce et al., 2002).

6.3. Costs and Burdens Associated with Depression

In 2000, the economic burden of depression was estimated at $83.1 billion, of which $26.1 billion was incurred by direct medical costs and nearly twice that amount ($51.5 billion) was associated with costs incurred in the workplace (Greenberg et al., 2003). Other research on depression-related costs in the workplace has shown that depressed workers who underperform as a result of their depression incur $35.7 billion in costs with another $8.3 billion incurred as a result of absenteeism among depressed workers (Stewart et al., 2003).

In addition to direct medical costs and lost productivity, depression is a leading cause of disability. It has been shown that older adults with depression have more physical limitations than do non-depressed adults (National Institute of Mental Health, 2007). In a study of the relationship between depression and comorbid illness, the severity of depression was strongly associated with decreased quality of life, decline in physical and mental functioning over time, as well as increased disability (Noel et al., 2004). There is also evidence to suggest that depression exacerbates existing physical problems among older adults, which may in turn exacerbate depression. For example, depression can enhance symptoms of arthritis, heart disease, hypertension, and diabetes (O'Connor et al., 2009). Loss of motivation resulting from depression can also pose challenges for effective treatment of these conditions because ongoing, active engagement on the part of the patient is critical for appropriate self-management (Noel et al., 2004). Moreover, lack of motivation and a sense of hopelessness can contribute to unfavorable health behaviors such as failure to engage in routine preventive care and health screenings, which can exacerbate existing chronic conditions, as well as depression associated with being chronically ill. These unfavorable depression-associated outcomes are observed not only among older adults, but also among people with disabilities. Poor self-management can reinforce depression by exacerbating the severity of existing chronic conditions (Katon and Guico-Pabia, 2011). Further, comorbid depression and chronic diseases such as angina, arthritis, asthma, and diabetes can lead to worse overall health than either depression or chronic disease alone (Moussavi et al., 2007).

It is therefore not surprising that depression is associated with increased health-care costs and utilization. Older adults with depression incur medical costs that are 50 percent higher relative to those without depression (Katon, 2003). These higher costs are incurred across a range of health care services, including primary-care visits, specialist visits, mental-health visits, pharmacy costs, x-ray examinations, and inpatient costs (Katon and Guico-Pabia, 2011). Older adults with depression have been shown to have 30 to 50 percent higher costs compared to their non-depressed counterparts, regardless of their level of co-morbidity (Unützer, 1997). These findings point to depression's independent contribution to health-care costs. Although studies have demonstrated clear links between social isolation and unfavorable health outcomes (Park, 2009), quantifying the costs associated with social isolation poses some difficulty since, unlike depression, it is not a diagnosable disorder that can be tracked using medical records and reimbursement data (Boden-Albala et al., 2005).

One factor that may contribute to the high costs associated with depression is that treatment is often not prioritized in primary care (Noel et al., 2004). Lack of appropriate depression treatment may eventually generate costs for these patients that could have been avoided with proper treatment. Despite the challenges associated with initiating treatment of depression, it has been reported that antidepressants are prescribed to approximately 14 percent of older adults over 65 (Olfson and Marcus, 2009). Although broadly effective, there is research to suggest that some therapies may exacerbate depressive symptoms in certain individuals (Qaseem et al., 2008) and others may increase the risk of falls (Fick et al., 2008). Thus, although effective pharmaceutical treatments for depression are available, in some cases, these treatments may result in unintended consequences that incur additional costs among depressed individuals.

Costs and burdens are also incurred among informal caregivers of depressed older adults and those with disabilities because the vast majority of care for these populations is provided by family and friends (AARP, 2011; Haley and Perkins, 2004). In one survey of depressed older adults, the value of informal caregiving was estimated at $9 billion annually (Langa et al., 2004). In addition to the costs associated with provision of informal care, caregivers of older adults with depression are themselves at higher risk of illness and mental-health problems as a result of the burdens associated with their caregiving roles. One frequently cited study demonstrated that mortality was 63 percent higher among caregivers experiencing mental and emotional strain caring for older adults than among non-caregivers or caregivers who did not report similar levels of strain (Schulz and Beach, 1999). For caregivers of adults with depression, one study found that 80 percent of caregivers reported distress and approximately 25 percent of these caregivers sought care themselves in the form of treatment or medication. One-third of the total sample felt able to cope with the patients' problems, but another one-third felt unable to do so. Caregiver distress was directly related to the severity and acuteness of patients' depression; the more severe and the more acute, the more likely caregivers were affected (van Wijngaarden, Schene, and Koeter, 2004).

6.4. Available Depression Management Technologies and Evidence of Their Benefits

Just as problems contributing to depression are varied and multidimensional, so too are technologies that aim to address this issue. Some of these technologies are geared toward facilitating access to mental-health professionals and services, others aim to promote social engagement, and still others seek to improve diagnosis of depression and reduce social isolation. These solutions approach specific elements of depression-related problems using telehealth, the internet, social media, and novel software applications, and often include combinations of these technologies. Many of these technology solutions are available for use in the home by patients to facilitate access to health-care professionals or to enhance social connectedness with family and friends.

Telemental Health Applications

Telemental health applications allow older adults who have difficulties with transportation as well as those who are homebound to access mental-health services that might otherwise be unavailable (American Telemedicine Association, 2009). These technologies are also valuable for older adults in rural areas where large distances create practical challenges for accessing routine mental-health care. Telemental health applications involve interactions between patients and a mental-health professionals that focus on patients' mental health and are facilitated by video-conferencing or telephone-based technologies. Telepsychiatry is one example of telemental health care where there is evidence to suggest that this approach provides measureable benefits to users. One study reported that telepsychiatry improved access to mental-health services, provided those services in an affordable and cost-effective manner, and delivered the services at a quality nearly equal to traditional face-to-face interactions (Sumner, 2008). There appears to be considerable evidence supporting the benefits of telemental health technologies. A review of 65 studies concluded that these approaches can offer efficient, cost-effective, and high-quality mental-health treatment (Hailey, Ohinmaa, and Roine, 2008). These technologies are in some ways an upgrade from existing telephonic clinical assessment tools. Depression scales such as the well-known Hamilton Depression Rating Scale have been validated for phone-based administration using touch-tone telephone and interactive voice response (IVR) technology (Kobak et al., 2000). Besides being able to reach disabled or geographically distant patients, significant advantages of telephone-based approaches over computer-based telehealth include usability and affordability for older adults or people with disabilities.

The Veterans Administration (VA) provides an example of how telemental health care can be used in combination with other technology-enhanced supports (Department of Veterans Affairs, 2010). VA technologies not only allow interactions between patients and mental-health professionals over long distances, but they also enable patients to complete questionnaires remotely, transmit vital signs, and access their own mental-health information. In these programs, personal computers allow patients access to videoconferencing and other mental-health resources, and videophones are distributed to patients without computers.

In addition to facilitating contact between patients and health-care providers, videoconferencing technologies can facilitate interactions between depressed individuals and their friends and family, thereby targeting problems associated with social isolation. Not only can videoconferencing be an effective approach to reducing social isolation and loneliness among affected persons, it can also minimize guilt and worry on the part of family members that can result from their not being able to visit affected relatives on a regular basis. These technologies therefore address depression-associated burdens experienced by both patients and their caregivers (Oliver et al., 2006). Application of videoconferencing technology is not limited to the home setting. One study found that low-cost videophones had the potential to enhance communication between nursing-home residents and their families, thereby allowing families to assume a more active role in care decisions, despite the practical challenges imposed by geographic distance (Mickus and Luz, 2002). The use of videoconferencing technology may be particularly relevant in long-term care settings because of the higher rates of depression that have been documented there (Watson et al., 2009).

Internet Use and Social Networking

Internet use for information consumption, entertainment, and maintaining contact with friends and family offers a way for older adults and people with disabilities to occupy their time and maintain connections outside of their immediate home environment. It is also a powerful technology that can be harnessed to address problems associated with social isolation and depression. There is evidence to suggest that internet use has positive effects on depression in older adults, that it facilitates the establishment of social networks that help alleviate feelings of loneliness and alienation, and that it provides a vehicle for remaining engaged in topics of interest. One study found that internet use enhanced older adults' overall well-being (Karavidas et al., 2005), and another showed that older adults who used the internet felt self-empowered and engaged in better self-management of their health (Shapira, Barak, and Gal, 2006). Although it has been suggested that older adults may find it challenging to use the internet, appropriate training and education can help address this problem (Hughes et al., 2008). For example, there are web-based resources (e.g., Generations OnLine) that assist older adults in learning to access and use the internet. These systems, which feature large-text directions and step-by-step instructions for navigating the web, aim to promote internet access and literacy among older adults.

The internet has fostered networking technologies such as chat rooms, news groups, and social-networking sites that have created vibrant and growing communities for older adults (Ariyachandra, Crable, and Brodzinski, 2009). These communities provide a multitude of interactive opportunities such as book clubs, interest groups, and support groups. In addition, many sites offer real-time chat capabilities, thereby enhancing the speed and quality of social interactions. Although these communities will never be a substitute for in-person interactions, many older adults and individuals with disabilities live far from their family and friends or are otherwise unable to maintain routine contact with loved ones during a hospitalization or a period of institutionalized rehabilitation. In these cases, social-networking sites can help prevent or reduce depression and social isolation by facilitating regular social interaction with family and friends (Phoenix Center, 2009). Although well-known social-networking sites such as Facebook and MySpace do not target a specific age group, some (e.g., eons) are dedicated specifically to older adults. The potential benefits of these sites were reflected in the findings of one study that found social-networking sites keep older adults active and interested, build mental acuity, and keep them informed about current events (Ariyachandra, Crable, and Brodzinski, 2009).

The internet and videoconferencing can be especially useful technologies for older adults and people with disabilities who are homebound and thus at particularly high risk of social isolation and depression. Web-based tools (e.g., the Virtual Senior Center) aim to connect homebound older adults using computer, video, and internet technology, when limited mobility, vision or hearing loss, or other disabilities might otherwise limit their social contacts and access to resources. Instead, this technology allows isolated older adults to connect with their peers and access community services, and may reduce social isolation and promote wellness in a group of particularly vulnerable older adults.

Software and Other Tools

In addition to the role that technology can play in facilitating receipt of mental-health services and reducing social isolation, some technologies focus on improving clinicians' ability to detect and ultimately diagnose depression. For instance, software applications can be used to administer depression screening questionnaires designed for older adults and a mechanism to transmit results to a designated provider (e.g., the Deep Pocket Series). Other applications have been developed to help older adults collect information on mood and other depression-related factors. For example, one health diary software application allows users to record mood and track sleeping, eating, and resting habits so that deviations can be identified and acted upon (e.g., Optimism Apps). Advances in touch-screen technology allow these software applications to run on touch-screen computers and smart phones, thereby facilitating access for older adults and individuals with disabilities.

Other technologies aimed at identifying depression can be worn by the user or incorporated into the living environment. Sensor-based monitoring technologies are an example of this approach. One wearable technology is an activity monitor used to identify deviations from normal behavior or social interaction patterns that are indicative of depression such as disrupted sleep or social withdrawal (Atallah et al., 2008). Another system consists of both wearable sensors and those that are embedded in the user's environment. This system tracks both physiological and behavioral data in real-time, thereby facilitating depression monitoring and enabling caregivers and families to act quickly if abnormal activity is detected (Becker and Webbe, 2008).

Video games are another class of software products that may offer promise for mitigating depression in old age. They are increasingly marketed towards middle-aged and older adults and are thus becoming especially popular among these age groups (Cohen, 2006). Older adults often choose games based on their familiarity and interest (e.g., golf or Wheel of Fortune) and they are frequently interested in games with a perceived meaningful purpose, such as improving motor, social, or educational skills (Aison et al., 2002). Due to the link between sedentary lifestyle and depression, video games that encourage users to be physically active may be particularly effective in addressing depression (Jones and Lenhart, 2008). Moreover, games that involve both movement and interaction with other players may offer the additional benefit of reducing social isolation (Rosenberg et al., 2010). Finally, the interactive nature of these games can help develop technology-based gaming communities within congregate care or residential settings in which older adults get together to use these gaming technologies.

6.5. Depression Technologies Under Development

The diverse causes of depression and challenges associated with treating depression have led to the development of a number of innovative technologies aimed at managing this complex condition. Novel approaches to social networking offer an example of evolving technologies aimed at addressing social isolation (Smith, Segal, and Segal, 2010). The Butler System is one technology that features a multi-user internet platform that serves as a social network among older adults who have profiles in the system. Each user has access to self-administered questionnaires embedded in software applications that monitor emotional health, and users can send and receive e-mail, have videoconferences, create personalized blogs or photo albums, and meet new people through the network. A recent study showed that this system improved quality of life and reduced negative mood and feelings of isolation (Etchemendy et al., 2011).

Researchers are currently developing a system that allows older adults to listen to music and news through an interface that facilitates social contact and stimulates affective experiences (Nilsson et al., 2003). This technology involves a table-top radio that is used with a fabric table runner. The table runner is divided into sections representing historical periods. Users press on areas of the table runner to select news and music from the period of their choice. A second prototype was designed to provide older adults with continuous information on their network of social contacts. This network is also accessible to caregivers who can monitor social interactions and intervene if isolation is evident (Morris, 2005). Preliminary testing on both systems suggested that exposure to these technologies increased social engagement and facilitated maintenance of daily activities.

Another evolving technology designed to encourage social interaction is a social synchronizer. This prototype system is intended to facilitate spontaneous interactions and activities among companions. The system signals opportunities for companions to join one another for social engagement. For example, if two older adults wish to take a walk together, the device signals when one individual is about to leave home and invites the other to join in. The device also notifies both of these individuals when their activity levels are low by sending alerts to companions, along with prompts to initiate engagement. Finally, the system integrates activity-tracking sensors that detect and log activity in the household. This function involves installation of sensors around the home that track the user with cameras via an infrared beacon worn by the user (Morris et al., 2004). A robot that is powered by artificial intelligence to assume the role typically filled by a live animal engaged in pet therapy is another example of evolving technologies aimed at managing depression. Preliminary data from this robot suggest that it reduces feelings of depression among older adults (Wada et al., 2005).

Another new innovative approach to depression screening is electrovestibulography. This technique can be applied to a diverse group of conditions--from Parkinson's Disease to schizophrenia--and may offer promise for identifying depression. Electrovestibulography measures and digitally analyzes electrical signals produced by the vestibular system (the part of the brain and inner ear that senses orientation of the head with respect to gravity) during certain movements, such as changes in head position. This evolving technique is being used to assess electrical activity patterns in the brain and compare these patterns to established norms in order to identify psychological and central nervous system disorders, including depression (Monash University, 2009). Although it may not be the most efficient or accessible method of diagnosing depression, electrovestibulography highlights the growing potential of biometric data to diagnose common chronic and disabling conditions such as depression. Another innovative technology that is under development to identify depression involves voice recognition software that measures the tone and rhythm of a patient's speech (Hsu, 2009). In the future, this technology has the potential to facilitate detection of depression using a traditional telephone, an approach that may be particularly appealing to older adults because of its low cost and ease of use.

6.6. Experiences of Other Countries with Depression Management Technologies

Similar to those available in the United States (U.S.), depression-related technologies developed outside of the U.S. often aim to address the problem by facilitating social interaction. For example, Knowledgeable Service Robots for Aging (KSERA) technology is being developed by Eindhoven University of Technology. This robotic assistant is programmed to monitor the health and behaviors of older adults and to report clinically meaningful changes to health care providers. KSERA provides video- and internet-based capabilities and can also potentially benefit older adults with depression by reducing social isolation. In addition, KSERA transmits automatic alerts to caregivers and emergency personnel and can facilitate prompt receipt of medical services when they are needed (KSERA, 2010).

A robotic technology developed in France is designed to assist older adults by speaking, understanding what others are saying, finding its way around the house, and accessing internet services (Savov, 2010). This device features a touch-screen display that allows users to access calls from family members or health care professionals through programs such as Skype, and it can interface with social networking sites such as Facebook. This technology may not only help older adults remain connected with close friends and family, but it may also allow providers to monitor physical and behavioral data for signs of depression.

The Open architecture for Accessible Services Integration and Standardization (OASIS) project is another innovative technology that targets older adults with depression. OASIS creates services that support socialization using smart applications. It features an architecture in which more than a dozen different services, such as nutritional advisors and activity coaches, can be integrated on different mobile devices. The goal of the OASIS project is to personalize technology to enhance the older adult's quality of life in a manner that is tailored to their mental and physical needs (OASIS, 2012).

In Portugal, developers are examining ways to enhance older adults' social networks through interactive television and social media web sites. These sites are designed to maintain contact among friends and to engage those who have common interests and practices. The interactive TV prototype is created to incorporate a number of activities, including accessing the TV to play traditional children's games; posting opinions, comments and personal stories; and creating and sharing content using digital photos and videos (Damasio and Quico, 2004).

Devices with monitoring functions and those requiring a direct interface with caregivers and providers need infrastructure for support. Support centers such as these exist in Europe and are assisted by various governments, including that of the European (EU). For instance, the United Kingdom (U.K.) supports telecare infrastructures that promote technologies that aim to prevent, monitor, and detect depression among older adults (European Commission, 2010).

References

Aison, C., Davis, G., Milner, J., Targum, E. (2002). Appeal and interest of video game use among the elderly. Harvard Graduate School of Education, i-28. http://www.booizzy.com/jrmilner/portfolio/harvard/gameselderly.pdf.

AARP (2011). Valuing the invaluable: 2011 Update -- The growing contributions and costs of family caregiving. http://assets.aarp.org/rgcenter/ppi/ltc/i51-caregiving.pdf. Accessed April 3, 2012.

American Telemedicine Association (2009). Evidence-based practice for telemental health. http://www.americantelemed.org/files/public/standards/EvidenceBasedTelementalHealth_WithCover.pdf. Accessed April 3, 2012 2012.

American Psychiatric Association (2000). *Diagnostic and statistical manual of mental disorders, Fourth Edition, Text Revision: DSM-IV-TR*. Washington, D.C.: American Psychiatric Publishing, Inc.

Ariyachandra, T., Crable, E., Brodzinski, J. (2009). Senior's perceptions of the web and social networking. *Issues in Information Systems,* X(2), 321-332.

Arnadottir, S.A., Gunnarsdottir, E.D., Stenlund, H., Lundin-Olsson, L. (2011). Participation frequency and perceived participation restrictions at older age: Applying the International Classification of Functioning, Disability and Health (ICF) framework. *Disability and Rehabilitation,* 33(23-24), 2208-2216.

Atallah, L., Lo, B., Guang-Zhong Y., Siegemund, F. (2008). Wirelessly accessible sensor populations (WASP) for elderly care monitoring. 2nd International Conference on Pervasive Computing Technologies for Healthcare, 2-7.

Becker, S.A., Webbe, F.M. (2008). The potential of hand-held assistive technology to improve safety for elder adults aging in place. In K. Henrikson, J.B. Battles, M.A. Keyes, M.L. Grady (Eds.). Rockville, M.D.: Agency for Healthcare Research and Quality and Alzheimer's Association. http://www.ahrq.gov/downloads/pub/advances2/vol4/Advances-Becker_3.pdf. Accessed April 3, 2012.

Biordi, D., Nicholson, N. (2009). Social Isolation. In P. Larsen, & I. Lubkin, Chronic illness: impact and intervention,Vol. 7, 85-115. Sudbury, Massachusetts: Jones and Barlett.

Boden-Albala, B., Litwak, E., Elkind, V., Rundek, T., Sacco, R. (2005). Social isolation and outcomes post stroke. *Neurology,* 64(11), 1888-1892.

Breen, L., O'Connor, M. (2011). Family and social networks after bereavement: experiences of support, change and isolation. *Journal of Family Therapy,* 33(1), 98-120.

Bruce, M.L., McAvay, G.J., Raue, P.J., Brown, E.L., Meyers, B.S., Keohane, D.J., Jagoda, D.R., Weber, C. (2002). Major depression in elderly home health care patients. *American Journal of Psychiatry,* 159(8), 1367-1374.

Centers for Disease Control and Prevention (2009). Depression is not a normal part of growing older. Atlanta, G.A.: U.S. Department of Health and Human Services. http://www.cdc.gov/aging/mentalhealth/depression.htm. Accessed April 3, 2012.

Chapman, D.P., Perry, G.S. (2008). Depression as a major component of public health for older adults. Preventing Chronic Disease, 5(1). http://www.cdc.gov/pcd/issues/2008/jan/07_0150.htm. Accessed April 3, 2012.

Cohen, A. (2006). Video-game makers discover a new, older, market. NPR. http://www.npr.org/templates/story/story.php?storyId=6589941. Accessed April 3, 2012.

Cole, M., Dendukuri, N. (2003). Risk factors for depression among elderly community subjects: A systematic review and meta-analysis. *American Journal of Psychiatry,* 160(6), 1147-1156.

Damasio, M., Quico, C. (2004). T-learning and interactive television edutainment: the Portuguese case study, ED-Media 2004, 4511-4518.

Department of Veterans Affairs (2010).Clinical videotelehealth. http://www.telehealth.va.gov/real-time/index.asp. Accessed April 3, 2012.

Etchemendy, E., Baños, R.M., Botella, C., Castilla, D., Alcañiz, M., Rasal, P.,Farfallini, L. (2011). An e-health platform for the elderly population: The butler system. *Computers & Education,* 56(1), 275-279.

European Commission (2010). ICT & Ageing: European study on users, markets, and technologies. http://ec.europa.eu/information_society/activities/einclusion/library/studies/docs/ict_ageing_final_report.pdf. Accessed April 3, 2012.

Fick, D., Mion, L., Beers, M., Waller, J. (2008). Health outcomes associated with potentially inappropriate medication use in older adults. *Research in Nursing and Health,* 31(1), 42-51.

Findlay, R. (2003). Interventions to reduce social isolation amongst older people: where is the evidence. *Ageing & Society,* 23(5), 647-658.

Gaboda, D., Lucas, J., Siegel, M., Kalay, E., Crystal, S. (2011). No longer undertreated? Depression Diagnosis and antidepressant therapy in elderly long-stay nursing-home residents, 1999 to 2007. *Journal of the American Geriatrics Society*, 59(4), 673-680.

Greaves C.J., Farbus, L. (2006). Effects of creative and social activity on the health and well-being of socially isolated older people: Outcomes from a multi-method observational study. *Journal of the Royal Society of Health,* 126(3), 134-142.

Greenberg P.E., Kessler R.C., Birnbaum H.G, Leong S.A., Lowe S.W., Berglund P.A., Corey-Lisle P.K. (2003). The economic burden of depression in the United States: how did it change between 1990 and 2000? *Journal of Clinical Psychology*, 64(12), 1465-1475.

Hailey, D., Roine, R., Ohinmaa, A. (2008). The effectiveness of telemental health applications: a review. *Canadian Journal of Psychiatry,* 53(11), 769-78.

Haley, W.E., Perkins, E.A. (2004). Current status and future directions in family caregiving and aging people with intellectual disabilities. *Journal of Policy and Practice in Intellectual Disability*, 1(1), 24-30.

Hsu, J. (2009). Voice analysis software could detect depression over the phone. PopSci. http://www.popsci.com/technology/article/2009-11/voice-analysis-software-could-detect-depression-over-phone. Accessed April 3, 2012.

Hughes, I., Mathews, M., Pourghasem, M., Shima, S. (2008). How the internet affects seniors' social capital and wellbeing. *Internet Technology and Social Capital,* 14(1), 202-220.

Jones, S., Lenhart, A. (2008).Video Games: Adults are players too. Pew Research Center Publications. http://pewresearch.org/pubs/1048/video-games-adults-are-players-too. Accessed April 4, 2012.

Karavidas, M., Lim, N.K., Katsikas, S.L. (2005).The effects of computers on older adult users. *Computers in Human Behavior*, 21(5), 697-711.

Katon, W. (2003). Clinical and health services relationships between major depression, depressive symptoms and general medical illness. *Biological Psychiatry,* 54(3), 216-226.

Katon, W., Guico-Pabia, C.J. (2011). Improving quality of depression care using organized systems of care: A review of the literature. T*he Primary Care Companion for CNS Disorders*, 13(1), e1-e8.

Knowledgeable Service Robots for Aging (2010). Knowledgable service robots for aging. http://www.ksera-project.eu. Accessed April 3, 2012.

Kobak, K.A., Mundt, J.C., Greist, J.H., Katzelnick, D.J., Jefferson, J.W. (2000). Computer assessment of depression: Automating the Hamilton Depression Rating Scale. *Drug Information Journal*, 34(1), 145-156.

Langa, K.M. Valenstein, M.A. Fendrick, A.M. Kabeto, M.U. Vijan, S. (2004). Extent and cost of informal caregiving for older Americans with symptoms of depression. *American Journal of Psychiatry,* 161(5), 857-863

Lyness, J.M., Heo, M., Datto, C.J., Ten Have, T.R., Katz, I.R., Drayer, R., Reynolds, C.F.III, Alexopoulos, G.S., Bruce, M.L. (2006). Outcomes of minor and subsyndromal depression among elderly patients in primary care settings. *Annals of Internal Medicine,* 144(7), 496-504.

MedlinePlus (2010). Depression -- elderly. Bethesda, M.D.: U.S. Department of Health and Human Services. http://www.nlm.nih.gov/medlineplus/ency/article/001521.htm. Accessed April 3, 2012.

Mickus, M., Luz, C. (2002).Televisits: Sustaining long distance family relationships among institutionalized elders through technology. *Aging and Mental Health,* 6(4), 387-396.

Monash University (2009). “ECG for the mind” could diagnose depression in an hour. ScienceDaily. http://www.sciencedaily.com/releases/2009/10/091015091611.htm. Accessed April 3, 2012.

Morris, M., Lundell, J., Dishman, E. (2004). Catalyzing social interaction with ubiquitous computing: A needs assessment of elders coping with cognitive decline. Conference on Human Factors in Computing Systems,1151-1154.

Morris, M. (2005). Social networks as health feedback displays. *IEEE Internet Computing,* 9(5), 29-37.

Moussavi, S., Chatterju, S., Verdes, E., Tandon, A., Patel, V., Ustun, B. (2007). Depression, chronic diseases, and decrements in health: Results from the World Health Surveys. *The Lancet*, 370(9590), 851-858.

Mynatt, E., Adler, A., Ito, M., Linde, C., O'Day, V. (1998). The network communities of SeniorNet. European Conference on Computer-Supported Cooperative Work 1-21. Copenhagen: European Society for Socially Embedded Technologies.

Nilsson, M., Johanson, S., Hakansson, M. (2003). Nostalgia: An evocative tangible interface for elderly users. Conference on Human Factors in Computing Systems, 964-965.

National Institute of Mental Health (2011). Depression. Bethesda, M.D.: U.S. Department of Health and Human Services. NIH Publication No. 11-3561. http://www.nimh.nih.gov/health/publications/depression/index.shtml. Accessed April 3, 2012.

National Institute of Mental Health (2007). Older adults: Depression and suicide facts (Fact Sheet). Bethesda, M.D.: U.S. Department of Health and Human Services. NIH Publication No.4593. http://www.nimh.nih.gov/health/publications/older-adults-depression-and-suicide-facts-fact-sheet/index.shtml. Accessed April 3, 2012.

Noel, P., Williams, J., Unutzer, J., Worchel, J., Lee, S., Cornell, J., Katon, W., Harpole, L.H., Hunkeler, E. (2004). Depression and comorbid illness in elderly primary care patients: Impact on multiple domains of health status and well-being. *Annals of Family Medicine,* 2(6), 555-562.

OASIS Project (2008). Quality of life for the elderly. http://www.oasis-project.eu/. Accessed April 3, 2012.

O'Connor, E.A., Whitlock, E.P., Gaynes, B., Beil, T.L. (2009). Screening for depression in adults and older adults in primary care: An updated systematic review. AHRQ Publication No. 10-05143-EF-1. Rockville, M.D: Agency for Healthcare Research and Quality. http://www.uspreventiveservicestaskforce.org/uspstf09/adultdepression/addepres.pdf. Accessed April 3, 2012.

Olfson, M., Marcus, S.C. (2009). National patterns in antidepressant medication treatment. *Archives of General Psychiatry,* 66(8), 848-856.

Oliver, D.P, Demiris, G., Hensel, B. (2006). A promising technology to reduce social isolation of nursing-home residents. *Journal of Nursing Care Quality,* 21(4), 302-305.

Park, N.S. (2009). The relationship of social engagement to psychological well-being of older adults in assisted living facilities. *Journal of Applied Gerontology*, 28(4), 461-481.

Perlick, D., Miklowitz, D., Link, B., Struening, E., Kaczynski, R., Gonzalez, J., Manning, L. Wolff, N., Rosenheck, R. (2007). Perceived stigma and depression among caregivers of patients with bipolar disorder. *The British Journal of Psychiatry*, 190, 535-536.

Phoenix Center for Advanced Legal and Economic Policy Studies. (2009). Internet use and depression among the elderly. http://www.phoenix-center.org/pcpp/PCPP38Final.pdf. Accessed April 3, 2012.

Prinz, L., Cramer, M., Englund, A. (2008).Telehealth: A policy analysis for quality, impact on patient outcomes, and political feasibility. *Nursing Outlook,* 56(4), 152-158.

Qaseem, A., Snow, V., Denberg, T.D., Forciea, M.A., Owens, D.K. (2008). Using second-generation antidepressants to treat depressive disorders: A clinical practice guideline from the American College of Physicians. Annals of Internal Medicine, 149(10), 725-733.

Rosenberg, D., Depp, C., Vahia, I., Reichstadt, J., Palmer, B., Kerr, J., Norman, G., Jeste, D. (2010). Exergames for subsyndromal depression in older adults: A pilot study of a novel intervention. *American Journal of Geriatric Psychiatry,* 18(3), 221-226.

Russo, C.A., Hambrick, M.M., Owens, P.L. (2007). Hospital stays related to depression, 2005. Rockville, M.D.: Agency for Healthcare Research and Quality. http://www.hcup-us.ahrq.gov/reports/statbriefs/sb40.pdf. Accessed April 3, 2012.

Savov, V. (2010). Robosoft Kompai takes care of your elderly so you don't have to. Engadget. http://www.engadget.com/2010/03/10/robosoft-kompai-takes-care-of-your-elderly-so-you-dont-have-to/. Accessed April 3, 2012.

Schulz, R., Beach, S. (1999). Caregiving as a risk factor for mortality. *Journal of the American Medical Association,* 282(23), 2215-2219.

Shapira, N., Barak, A., Gal, I. (2006). Promoting older adults' well-being through Internet training and use, *Aging & Mental Health,* 11(5), 477-484.

Smith, M., Segal, R., Segal, J. (2010). Depression in older adults and the elderly. http://helpguide.org/mental/depression_elderly.htm. Accessed April 3, 2012.

Stewart W.F., Ricci J.A., Chee E., Hahn S.R., Morganstein D. (2003). Cost of lost productive work time among U.S. workers with depression. *Journal of the American Medical Association*, 289(23), 3135-3144.

Sumner, C.R. (2008). Telepsychiatry: Challenges in rural aging. *The Journal of Rural Health,* 17(4), 370-373.

Unützer, J., Patrick, D., Simon, G., Grembowski, D., Walker, E., Rutter, C., Katon, W. (1997). Depressive symptoms and the cost of health services in HMO patients aged 65 years and older. *Journal of the American Medical Association,* 277(20), 1618-1623.

Victor, C.R., Scambler, S.J., Shah, S., Cook, D. G., Harris, T., Rink, E., de Wilde, S. (2002). Has loneliness amongst older people increased? An investigation into variations between cohorts. *Ageing and Society,* 22(5), 585-598.

Van Wijngaarden, B., Schene, A.H., Koeter, M.W.J. (2004). Family caregiving in depression: Impact on caregivers' daily life, distress, and help seeking. *Journal of Affective Disorder*, 81, 211-222.

Wada, K., Shibata, T., Saito, T., Sakamoto, K., Tanie, K. (2005). Psychological and social effects of one year robot assisted activity on elderly people at a health service facility for the aged. 2005 Institute of Electrical and Electronics Engineers Conference on Robotics and Automation, 2785-2790.

Watson, L.C., Zimmerman, S., Cohen, L.W., Dominik, R. (2009). Practical depression screening in residential care/assisted living: Five methods compared with gold standard diagnoses. *American Journal of Geriatric Psychiatry*, 17(7), 556-564.

CHAPTER 7: MOBILITY IMPAIRMENT

7.1. Definition of Mobility Impairment

Mobility impairment is sometimes understood narrowly as a limitation in ambulation. In the disability arena, however, it is defined as a limitation or inability to use one or more extremity, or a lack of strength to walk, grasp, or lift objects. Mobility impairment can result from a multitude of factors including injury, disease, or congenital disorder, and as such can lead to temporary or chronic loss of function (Colorado State University, 2012). Functionally, mobility impairment is also associated with limitations in basic tasks such as activities of daily living (ADLs), which include using the bathroom, dressing, and bathing. Loss of ADL abilities, in turn, is a strong risk factor for overall loss of independence.

A number of common chronic conditions can lead to mobility impairment. Neurological conditions such as Parkinson's disease and stroke, arthritis, visual impairment, hip fractures, obesity, and respiratory conditions can all limit mobility (Walsh, Roberts, and Bennett, 1999; Centers for Disease Control and Prevention, 2010a; Vincent, Vincent, and Lamb, 2010; Abe et al., 2011). In particular, arthritis and obesity both contribute to wear on the knees and hips, two joints that are critical for lower-extremity mobility. Mobility impairment often occurs simultaneously with other chronic conditions, which can exacerbate both conditions. Further, the sedentary behavior that characterizes immobile individuals is a risk factor for other conditions and syndromes, including decubitus ulcers (bedsores), loss of bone density, and frailty. For example, mobility impairment can lead to weight gain and obesity, conditions that can exacerbate mobility impairment by preventing exercise that could improve mobility status (Lindgren et al., 2004; Chen et al., 2006). Because mobility impairment can inhibit individuals' ability to leave their homes and interact with others, it can also contribute to social isolation and depression, topics that are discussed in Chapter 6 of this report. Mobility impairment can also be caused by other factors such as accidents or congenital disorders and, depending on the nature of these factors, can be long-term or temporary. The technologies that are described in this chapter offer assistance to individuals with both temporary and permanent mobility impairments.

Mobility impairment presents a number of specific challenges to patients, caregivers, and health-care professionals. For patients, these difficulties can include challenges with movement and navigation around obstacles, loss of lower-extremity strength and range of motion, a growing need for assistance from others with ADLs, and difficulty in accessing medical facilities and services. Mobility impairment presents challenges to clinicians, including lack of accurate information on immobile individuals' daily activities and movement patterns, which might be used to identify and implement strategies to mitigate the health problems that both cause and result from mobility impairment. Caregivers and health-care professionals often experience injuries associated with caring for immobile individuals because of the frequent need to lift and transfer these individuals.

7.2. Prevalence of Mobility Impairment

Mobility impairment affects large portions of the older population and populations with disabilities, and is often a result of the pathological effects of common chronic diseases of aging. Mobility impairment is often assessed using surveys that ascertain information such as walking abilities and ADL performance, and to a lesser degree in specialized studies that focus in depth on mobility itself. In 2010, among community-dwelling adults, 1 percent of those age 18 to 45, 2 percent of those age 45 to 64, 4 percent of those age 65 to 74, and 11 percent of those age 75 and over had ADL limitations; while 1 percent, 4 percent, 7 percent and 19 percent of these age groups, respectively, had limitations performing instrumental activities of daily living (IADLs) such as shopping and cleaning (Centers for Disease Control and Prevention, 2011b). The prevalence of these limitations is clearly much higher among those living in institutional settings. Although difficulty with ADLs and IADLs can be the result of mobility impairment, other factors may also influence the ability to perform these activities. For example, cognitive decline, sensory impairment, and functional decline (discussed in Chapter 4, Chapter 5, and Chapter 8, respectively) can significantly impact an individual's ability to perform ADLs and IADLs, in conjunction with or independent of mobility impairment.

Mobility impairment increases in tandem with other chronic conditions of aging. For example, mobility impairment increases as visual impairments increase; visual impairments among older adults are in turn associated with a greater likelihood of bumping into obstacles and decreased walking speed (Turano et al., 2004). Similarly, arthritis affects 34 percent of adults age 65 and over and this condition is also a risk factor for mobility impairment: 80 percent of patients with arthritis report having some degree of movement limitation (Centers for Disease Control and Prevention, 2011a). Rarer conditions such as rheumatoid arthritis and Parkinson's disease also limit mobility. Parkinson's, which affects between 2 and 4 percent of older people, causes difficulty initiating voluntary movements, loss of balance, rigid muscles, and pain, all symptoms that inhibit mobility (Nussbaum and Ellis, 2003). Obesity is a major cause of mobility impairment regardless of age. According to the National Health Interview Survey, 28 percent of people age 18 to 49 experience mobility difficulties and are obese (Iezzoni et al., 2001), putting them at increased risk of greater challenges with mobility and other types of disability.

Hip fractures are a major risk factor for mobility impairment among older adults. Although the rate of hip fracture among this population has declined over the last 20 years, it remains a leading cause of disability in old age (Stevens and Anne-Rudd, 2010). Hip fractures are discussed further in Chapter 1, which focuses on falls.

Mobility impairment may result from paralysis due to various causes, such as spinal cord injury. Approximately 5.3 million people in the U.S. suffer from paralysis, with 1.3 million suffering from it due to spinal cord injury. Other causes of paralysis include multiple sclerosis (939,000 cases), cerebral palsy (412,000 cases), and traumatic brain injury (242,000 cases). The causes of paralysis affect people of all ages, not just older adults (Christopher and Dana Reeve Foundation, 2012a; Rubin, 2009). Paralysis is especially prevalent among military personnel who account for 7 percent of people paralyzed due to an accident-related injury (Christopher and Dana Reeve Foundation, 2012b).

7.3. Costs and Burdens Associated with Mobility Impairment

Older adults and others with mobility limitations are susceptible to debilitating, costly medical conditions and procedures, including bedsores, and knee and hip replacements. Additionally, mobility-impaired individuals often require extensive assistance, either from professional or informal caregivers in performing daily living activities. Professional assistance, especially institutionalized care, can be extremely expensive. Moreover, informal caregivers also suffer financial burdens as their caregiving responsibilities may cut into their work time and productivity.

Bedsores offer one example of a costly medical problem that originates in part from mobility impairment. Bedsores are caused by prolonged pressure that interrupts delivery of oxygen and nutrients to the skin. Problems resulting from bedsores can range from mild irritation to severely infected wounds that may expose both bone and muscle. Mobility impairment increases the risk of bedsores because affected individuals often remain sedentary for long periods of time, thereby increasing pressure in concentrated areas. Approximately 10 percent of nursing-home residents age 64 and over experience bedsores (Centers for Disease Control and Prevention, 2009a). In 2006, 503,300 hospital admissions were attributed to bedsores, with costs totaling $11 billion (Agency for Healthcare Research and Quality, 2008).

Knee and hip replacement are surgical approaches to addressing mobility impairment among both older individuals and people with disabilities. In 2009, 364,000 knee replacement and 158,000 hip replacement procedures were performed on people age 65 and older (Centers for Disease Control and Prevention, 2009b). The average cost in 2004 for knee replacement surgery was $13,200 and the average cost for hip replacement surgery was $14,500 (Wilson et al., 2008).

Reduced mobility is a leading cause of long-term care service utilization. According to a meta-analysis of nursing-home admissions studies, difficulty performing three or more ADLs predicted admission into nursing homes. A 1999 survey of nursing-home residents identified the most common ADLs with which residents needed assistance and showed that one in three residents were admitted with conditions that impaired their ability to walk and that these residents required daily assistance with walking (Gaugler et al., 2007; Centers for Disease Control and Prevention, 1999).

Many older adults and others with disabilities suffering from mobility limitations receive informal care from family members or friends. For example, older adults who experience a fall because of mobility impairment or who sustain fall-related injuries that result in mobility impairment may be unable to care for themselves, manage their households, or run errands while they recover from their injuries. Older adults and people with disabilities who do not regain the ability to walk are at extremely high risk of permanent loss of independence, which further elevates the importance of informal caregivers. In addition to the physical and psychological burdens of caregiving, there are economic implications for these caregivers. In 2007, the value of informal caregiving was estimated to be $375 billion per year (AARP, 2008). Caregivers encounter costs in the form of lost wages, pensions, earned interest, employer matched retirement savings, Social Security benefits, and out-of-pocket expenses. Caregivers who live near the person for whom they care have the lowest yearly costs, $4,570 in annual out-of-pocket expenses; caregivers who live with the person they care for have $5,885 in annual out-of-pocket expenses; and other caregivers have $8,728 in annual out-of-pocket-expenses (AARP, 2008).

7.4. Available Mobility Impairment Technologies and Evidence of Their Benefits

A number of technologies are available to support older adults and people with disabilities who are challenged by mobility limitations. Although most of these technologies address the needs of the user, some provide support for caregivers or information for health-care professionals.

Neuromuscular Electrical Stimulation for Rehabilitation

Neuromuscular electronic stimulation (NMES) is a technological advancement that uses a power source and electrodes placed on the skin to provide low-voltage electrical impulses to stimulate weakened muscle groups. The device delivering NMES can be used to strengthen muscles and improve mobility among patients with certain chronic diseases, as well as those who are confined to bed for extended periods of time (Needham, Truong, and Fan, 2009). Data from another study showed that older adults with chronic obstructive pulmonary disease (COPD) who used NMES devices experienced improved muscle function, improved ability to perform endurance activity, and no longer exhibited breathlessness after combining NMES with their exercise regimen (Neder, Sword, and Ward, 2002). When NMES was combined with routine physical therapy, patients showed increased muscle strength relative to those who had physical therapy alone (Needham, Truong, and Fan, 2009).

Wheeled Mobility Equipment

Wheeled mobility equipment is effective in preserving the independence of individuals with mobility impairments (Trefler et al, 2004; Martorello and Swanson, 2006). This class of assistive devices includes manual and power wheelchairs as well as scooters. While manual, four-wheeled chairs are propelled by the user, power wheelchairs are heavier pieces of equipment that have four to six wheels, are powered electrically, and are guided using a hand-held joystick. Scooters differ slightly from wheelchairs in that they have three or four wheels, are controlled with handlebars, and have more precise turning radiuses relative to power wheelchairs. Compact scooters are scooters that can be folded for easy storage (Disabled World, 2009).

Newer electric wheelchairs include both reclining and upright models. Reclining wheelchairs allow the user to manually shift the incline of the chair, ranging from a seated to a reclining position. This feature allows the user to improve circulation to the lower extremities and guard against decubitus ulcers. The upright model allows users to move from a seated to a supported standing position. This technology allows the user to have a greater range of motion and to maintain a higher level of independence by permitting the user to reach high places such as cabinets and sinks without assistance (Cooper and Cooper, 2009). To address patients' susceptibility to bedsores, many high-tech wheelchair and scooter cushions are adjustable, allowing patients to alternate the seated pressure on the body that often contributes to bedsores. The pressure alternation schedule can be modified based on patients' needs.

New two-wheel mobility or "stand-up" technologies offer an additional option for mobility assistance. Unlike wheelchairs or scooters, these devices allow users to navigate their environment from a standing position. Stand-up technologies use a gyroscope to maintain stability and employ a vast network of sensors that respond to changes in user body position to brake, accelerate, and turn. This design allows users to move smoothly at high speeds and make quick and smooth turns around obstacles. The devices are available for indoor, outdoor, or multi-terrain use. Standing up can be appealing for users with mild to moderate mobility impairment that do not require seated technology, and for users concerned about the stigma of using seated mobility devices. However, stand-up technologies may also pose dangers for users with certain mobility impairments or conditions such as muscle weakness or compromised balance that may increase the risk of falling while operating such devices.

Mobility Aids

Mobility aids are devices such as crutches, canes, walkers, and lifts that help people move in their environment (U.S. Library of Medicine, 2010); they can also enable users to maintain independence and reduce health-care costs (Rentschler et al., 2003). Lifts have been adopted not only by consumers, but also by providers who use them to lift patients onto examination tables. Assisted lift chairs allow caregivers to move and lift immobile individuals in a manner that reduces risk of injury to both the caregiver and patient (Montemerlo et al., 2002). More traditional aids such as walkers, canes, and crutches are effective in assisting seniors in moving independently while supporting their weight and helping them to maintain their balance. While canes provide asymmetric support when only one is used, crutches ensure symmetric support that can prevent overexertion of one of the lower limbs (Wasson et al., 2008).

Physicians are required to make their practices accessible to people with disabilities, including mobility impairments. To comply with the ADA (Americans with Disabilities Act of 1990) requirements, they often use lift devices such as those discussed earlier as well as examination tables that can be lowered and raised as needed. Other aspects of the medical experience must also be accessible to immobile individuals, including wheelchair-accessible scales, mammography equipment, and other devices (U.S. Department of Justice, 2010).

Some mobility aids have been developed specifically for people with Parkinson's disease but can be useful for any mobility impairment. One type of aid is a walker that remains stable until the user lightly squeezes a handle break allowing the walker to move. This allows the walker to remain stable while the user is getting up or sitting down and keeps it stable until the user is ready to move. This aid also has a seat and is capable of rolling up curbs. Another aid is a cane that projects a bright red line across the user's path to indicate where their foot should fall as they take each step. This additional visual guidance can help improve the user's stride and confidence, and can assist in breaking Parkinson's-related "freezing episodes," which are characterized by the temporary loss of the ability to move and respond to visual cues such as laser-projected lines (National Parkinson Foundation, 2012).

Rehabilitative Devices

Some recent innovations target not the assistance, but the rehabilitation of mobility impairments. One currently available rehabilitative technology allows the user to safely practice and improve walking, balance, and posture with support in order to regain muscle strength and mobility. This device consists of a harness attached to an overhead, ceiling-mounted "trolley" that moves with patients as they walk, and a winch that supports a fraction of patients' body weight and is adjustable. This apparatus allows the user to engage in practical activities such as walking, sitting down, standing up, and walking up and down stairs without fear of falling or loss of balance and work toward eventually supporting their entire body weight during these activities. The device has been tested and deemed safe for people of a wide range of weights and walking speeds (Hidler et al., 2011).

Multi-Purpose Devices

There are several devices on the market for people in need of multiple assistive functions, including mobility assistance, rehabilitation, and lift functions. One such device provides the user with freedom of movement due to its wheelchair capacity, and its ability to raise the user to mid- to eye-level heights with a lift function, in some cases bringing the user to a standing position. Some chairs are designed to lift and transfer users to a bed, a car, or enable them to use the bathroom without assistance and therefore allow the user to live a more independent life. Certain chairs can also serve a dual rehabilitative function by providing support during exercise, in addition to their standard functionalities. Other multi-purpose devices can climb curbs or even stairs, while others have a power lift function that allows caregivers to maneuver a seated user up the stairs (National Institute of Standards and Technology, 2006). Advancements in multi-purpose devices of this nature increase their users' self-sufficiency in performing self-care and other activities that are dependent on mobility, and in doing so can also ease the burden of family and friends providing care to an impaired individual.

7.5. Mobility Impairment Technologies Under Development

Several technologies are currently under development that may help extend independence for individuals with mobility limitations. In general, these new technologies offer features that improve or enhance the functionality of existing technologies targeting people with mobility impairments. These include intelligent mobility aids such as autonomous wheelchairs and smart/robotic walkers, mobile robotic assistants, and improved rehabilitative devices.

An autonomous wheelchair is being developed at the Massachusetts Institute of Technology (MIT) that determines its location by using sensors to create a virtual map of the environment. This wheelchair is activated by voice commands, which may make it particularly appealing for users with limitations in both upper and lower extremity function (Computer Science and Artificial Intelligence Laboratory, 2008). The wheelchair "learns" the layout of the environment with voice instructions from the user or caregiver, and it can learn to return to a previously identified location in response to a verbal command. Researchers also intend to implement a collision-avoidance system in future models and add mechanical arms to allow users to pick up and manipulate objects (Chandler, 2008).

Technological developments are also leading to improvements in walkers. Traditionally, design of these devices has focused solely on the user's stability. Researchers are now developing robotic walkers that not only address stability, but also provide navigation functions that help users avoid obstacles even in narrow spaces. Researchers at Carnegie Mellon University are developing a robotic walker that can detect different surfaces, as well as varying surface conditions to help it find and navigate the most suitable path for the user. Researchers are also examining how to incorporate video messages in the walker that can alert users to their surroundings to provide additional supplementary information that contributes to both stability and mobility (Morris et al., 2003).

7.6. Experiences of Other Countries with Mobility Impairment Technologies

A new technology is being developed in Israel that monitors patients' sleep movements to assist caregivers and clinicians in preventing bedsores. The device can be placed under a patient's mattress to monitor movements during sleep. Care providers can then review this information and use the data to ensure that patients have shifted their bodies sufficiently during the night to avoid bedsores (Zimlichman, 2011).

Wheelchair technology that utilizes artificial intelligence is being developed in both Japan and Canada. A Japanese company has developed a wheelchair that can be controlled by the user's brain: sensors placed on the head transmit the brain's electrical impulses (i.e., the user's thoughts and intention to move) to an onboard laptop that collects, analyzes, and translates these impulses into commands that guide the wheelchair. Thus, instead of using the upper limbs to operate a joystick or turn a manual wheelchair, users simply "think" the directional command and the wheelchair will respond (Gonsalves, 2009).

In Canada, artificial intelligence is being leveraged to develop an autonomous wheelchair. Similar to the autonomous wheelchair being developed at MIT, this technology involves a wheelchair base that complies with a user's personalized settings and voice commands, and that can detect and avoid obstacles. The chair also includes a joystick that is capable of overriding the voice-controlled interface if the user desires (Applied AI Systems, 2010).

A number of technologies being developed outside the U.S. are dedicated to assisted walking. As discussed in Chapter 8 on functional decline, in Israel and Japan, robotic suits are being designed to assist individuals with mobility impairment. The robotic suit being developed in Israel is battery-operated and uses a combination of sensors that detect upper-body movement, body braces with motorized leg joints and crutches, and a small computer to process the incoming data and control the suit's motors. This device can both enhance the user's strength and compensate for muscle weakness, depending on the nature and severity of the impairment. The robotic suit being developed in Japan consists of robotic supports that can attach to the arms, legs, and torso, depending on the user's needs. When the wearer initiates movement, the brain sends nerve impulses to the relevant muscles, causing them to contract. These nerve signals generate electrical impulses on the surface of the skin. The device monitors these signals and then responds such that the assistive limbs move in coordination with the body. This device can assist individuals with more severe impairments recover lost movement, while enhancing the strength of those with less-severe muscle weakness. Ultimately, devices that provide support, enhancement, or recovery of function support users' independence and self-sufficiency and decrease reliance on assistive services or caregiving.

References

Applied AI Systems (2010). TAO-7 Intelligent Wheelchair Base for the Development of Autonomous Wheelchair. http://www.aai.ca/robots/tao_7.html. Accessed April 4, 2012.

AARP (2009). Valuing the invaluable: The economic value of family caregiving, 2008 update. http://assets.aarp.org/rgcenter/il/i13_caregiving.pdf. Accessed April 4, 2012.

AARP (2008). Valuing the invaluable: The economic value of family caregiving, 2008 update. http://assets.aarp.org/rgcenter/il/i13_caregiving.pdf. Accessed April 4, 2012.

Abe, T., Suzuki, T., Yoshida, H., Shimada, H., Inoue, N. (2011). The relationship between pulmonary function and physical function and mobility in community-dwelling elderly women aged 75 years or older. *Journal of Physical Therapy Science,* 23(3), 3443-449.

Aretech (2012). ZeroG. http://www.aretechllc.com/overview.html. Accessed April 4, 2012.

Agency for Healthcare Research and Quality (2008). Hospitalizations related to pressure ulcers among adults 18 years and older, 2006. Rockville, M.D.: U.S. Department of Health and Human Services. http://www.hcup-us.ahrq.gov/reports/statbriefs/sb64.pdf. Accessed April 4, 2012.

Centers for Disease Control and Prevention (1999). The National nursing home survey: 1999 summary. Atlanta, G.A.: U.S. Department of Health and Human Services. http://www.cdc.gov/nchs/data/series/sr_13/sr13_152.pdf. Accessed April 4, 2012.

Centers for Disease Control and Prevention (2009a). Pressure ulcers among nursing home residents United States, 2004. Atlanta, G.A.: U.S. Department of Health and Human Services. DHHS Publication No. 2009-1209. http://www.cdc.gov/nchs/data/databriefs/db14.pdf. Accessed April 4, 2012.

Centers for Disease Control and Prevention.(2009b). National Hospital Discharge Survey. Atlanta, G.A: U.S. Department of Health and Human Services. http://www.cdc.gov/nchs/data/nhds/4procedures/2009pro4_numberprocedureage.pdf. Accessed May 24, 2012.

Centers for Disease Control and Prevention (2010a). Arthritis-related statistics. Atlanta, G.A.: U.S. Department of Health and Human Services. http://www.cdc.gov/arthritis/data_statistics/arthritis_related_stats.htm. Accessed April 4, 2012.

Centers for Disease Control and Prevention (2011a). Osteoarthritis. Atlanta, G.A.: U.S. Department of Health and Human Services. http://www.cdc.gov/arthritis/basics/osteoarthritis.htm. Accessed April 4, 2012.

Centers for Disease Control and Prevention (2011b). Summary health statistics for the U.S. population: National health interview survey, 2010. Atlanta, G.A.: U.S. Department of Health and Human Services. http://www.cdc.gov/nchs/data/series/sr_10/sr10_251.pdf. Accessed May 28, 2012.

Chandler, D. (2008). Robot wheelchair finds its own way: MIT invention responds to user's spoken commands. MITNews. http://web.mit.edu/newsoffice/2008/wheelchair-0919.html. Accessed April 4, 2012.

Chen, J.S., Cameron I.D., Cameron, R.G., Lord, S.R., March, L.M., Sambrook, P.N., Simpson, J.M., Seibel, M.J. (2006). Effect of age-related chronic immobility on markers of bone turnover. *Journal of Bone and Mineral Research,* 21(2), 324-331.

Christopher and Dana Reeve Foundation (2012a). Paralysis resource center: Paralysis facts and figures. http://www.christopherreeve.org/site/c.mtKZKgMWKwG/b.5184189/k.5587/Paralysis_Facts__Figures.htm. Accessed April 4, 2012.

Christopher and Dana Reeve Foundation (2012b). One degree of separation: Paralysis and spinal cord injury in the United States. http://www.christopherreeve.org/site/c.mtKZKgMWKwG/b.5184243/k.96F9/Gender_paralysis_and_military_service.htm. Accessed April 4, 2012.

Colorado State University (2012). Mobility impairments: Definition. http://accessproject.colostate.edu/disability/modules/MI/tut_MI.cfm. Accessed April 4, 2012.

Computer Science and Artificial Intelligence Laboratory (2008). Autonomous wheelchair. http://www.csail.mit.edu/videoarchive/research/robo/autonomous-wheelchair. Accessed April 4, 2012.

Cooper, R.A., Cooper, R. (2009). Trends and issues in wheeled mobility technologies. http://www.ap.buffalo.edu/ideaproto/Space%20Workshop/index2.asp. Accessed April 4, 2012.

Disabled World (2009). Mobility scooters versus wheelchairs. http://www.disabled-world.com/assistivedevices/mobility/scooters/scooters-vs-wheelchairs.php. Accessed April 4, 2012.

Gaugler, J.E., Duval, S., Anderson, K.A., Kane, R.L. (2007). Predicting nursing home admission in the U.S: A meta-analysis. *BMC Geriatrics,* 7(13).

Gonsalves, A. (2009). Toyota develops mind-controlled wheelchair. InformationWeek. http://www.informationweek.com/news/218101872. Accessed April 4, 2012.

Hidler, J., Brennan, D., Black, I., Nichols, D., Brady, K., Nef, Tobias. (2011). ZeroG: Overground gait and balance training system. *Journal of Rehabilitation Research & Development,* 48(4), 287-298.

Iezzoni, L.I., McCarthy, E.P., Davis, R.B., Siebens, H. (2001). Mobility difficulties are not only a problem of old age. *Journal of General Internal Medicine,* 16(4), 235-243.

Lindgren, M., Unosson, M., Fredrikson, M., Ek, A.C. (2004). Immobility--a major risk factor for development of pressure ulcers among adult hospitalized patients: a prospective study. *Scandinavian Journal of Caring Sciences,* 18(1), 57-64.

Martorello, L., Swanson, E. (2006). Effectiveness of an automatic manual wheelchair braking system in the prevention of falls. *Assistive Technology,* 18(2), 166-169.

Montemerlo, M., Pineau, J., Roy, N., Thrun, S., Verma, V. (2002). Experiences with a mobile robotic guide for the elderly. 8^{th} National Conference on Artificial Intelligence of the Association for the Advancement of Artificial Intelligence, 587-592.

Morris, A., Donamukkala, R., Kapuria., A., Steinfeld, A., Matthews, J., Dunbar-Jacob, J., Thrun, S. (2003). A robotic walker that provides guidance. Proceedings of the International Conference on Robotics and Automation of the Institute of Electrical and Electronics Engineers, 25-30.

National Alliance for Caregiving. (2009). The Evercare survey of the economic downturn and its impact on family caregiving. http://www.caregiving.org/data/EVC_Caregivers_Economy_Report%20FINAL_4-28-09.pdf. Accessed April 4, 2012.

National Institute of Standards and Technology (2006). Survey of patient mobility and lift technologies: Toward advancements and standards. Gaithersburg, M.D.: U.S. Department of Health and Human Services. http://www.nist.gov/customcf/get_pdf.cfm?pub_id=823633. Accessed April 4, 2012.

National Parkinson Foundation (2012). Freezing. http://www.parkinson.org/Parkinson-s-Disease/Living-Well/Safety-at-Home/Freezing.aspx. Accessed April 4, 2012.

Neder, J., Sword, D., Ward, S. (2002). Home based neuromuscular electrical stimulation as a new rehabilitative strategy for severly disabled patients with chronic obstructive pulmonary disease (COPD). *Thorax ,* 57(4), 333-337.

Needham, D.M., Truong, A.D., Fan, E. (2009). Technology to enhance physical rehabilitation of critically ill patients. *Critical Care Medicine ,* 37(10 Suppl), S436-441.

Nussbaum, R.L., Ellis, C.E. (2003). Alzheimer's disease and Parkinson's disease. *The New England Journal of Medicine*, 348(14), 1356-64.

Rentschler, A., Cooper, R., Blasch, B., Boninger, M. (2003). Intelligent walkers for the elderly: Performance and safety testing of VA-PAMAID robotic walker. *Journal of Rehabilitation Research and Development,* 40(5), 423-432.

Rubin, R. (2009). Survey: More are paralyzed in U.S. than previously thought. USA Today. http://www.usatoday.com/news/health/2009-04-21-paralysis-survey_N.htm. Accessed April 4, 2012.

Stevens, J.A., Anne-Rudd, R. (2010). Declining hip fracture rates in the United States. *Age Ageing,* 39(4), 500-503.

Trefler, E., Fitzgerald, S.G., Hobson, D.A., Bursick, T., Joseph, R. (2004). Outcomes of wheelchair systems intervention with residents of long-term care facilities. *Assistive Technology,* 16(1), 18-27.

Turano, K.A., Broman, A.T., Bandeen-Roche, K., Munoz, B., Rubin, G.S., West, S.K., (2004). Association of visual field loss and mobility performance in older adults: Salisbury eye evaluation study. *Optometry and Vision Science,* 81(5), 298-307.

U.S. Department of Justice and U.S. Department of Health and Human Services (2010). Access to medical care for individuals with mobility disabilities. Washington, D.C.: U.S. Department of Justice. http://www.ada.gov/medcare_mobility_ta/medcare_ta.htm. Accessed April 4, 2012.

U.S. Library of Medicine. (2010). Mobility aids. Bethesda, M.D.: U.S. Department of Health and Human Services. http://www.nlm.nih.gov/medlineplus/mobilityaids.html. Accessed April 4, 2012.

Vincent, H.K., Vincent, K.R., Lamb, K.M. (2010). Obesity and mobility disability in the older adult. *Obesity Reviews*, 11(8), 568-579.

Walsh, K., Roberts, J., Bennett, G. (1999). Mobility in old age. *Gerodontology*, 16(2), 69-74.

Wasson, G., Sheth, P., Huang, C., Alwan, M. (2008). Intelligent mobility aids for the elderly. In R. Felder, M. Alwan, *Aging Medicine, Eldercare Technology for Clinical Practitioners*, 53-76, Totowa, NJ: Humana Press Inc.

Wilson, N.A., Schneller, E.S., Montgomery, K., Bozic, K.J. (2008). Hip and knee implants: Current trends and policy considerations. *Health Affairs,* 27(6), 1587-1598.

Zimlichman, E., Shinar, Z., Rozenblum, R., Levkovich, S., Skiano, S., Szyper-Kravitz, M., Altman, A., Amital, H., Shoenfeld, Y. (2011). Using continuous motion monitoring technology to determine patient's risk for development of pressure ulcers. *Journal of Patient Safety,* 7(4), 181-184.

CHAPTER 8: FUNCTIONAL DECLINE AND LOSS OF INDEPENDENCE

8.1. Definition of Functional Decline

Functional decline is a complex process triggered by one or more underlying pathologies that leads to impairment or functional limitations, and that may ultimately result in disability and institutionalization. There are numerous models for understanding age-related functional decline and loss of independence. Among these is a model that defines the disablement process as the interaction of acute and chronic health conditions with environmental factors that advance or delay loss of function (Verbrugge and Jette, 1994). Other experts view disability as impairments in bodily function that limit activities, including activities of daily living (ADLs), and restrict participation in society (Freedman, 2010). ADLs are basic activities that self-reliant people carry out on a daily basis, such as eating, walking, dressing, and bathing (Katz, 1963). Instrumental activities of daily living (IADLs) are other activities commonly associated with independent living, such as grocery shopping, housekeeping, and financial management (Lawton and Brody, 1969).

Functional decline is a broad term that can describe decreases in both physical and cognitive abilities and functionality. This chapter addresses the physical aspects of functional decline. Health-care professionals often assess physical decline in terms of markers, including: decline in physical activity levels and generalized “wellness” that signal the onset or worsening of pathology; gait and balance impairments that impact mobility and increase the risk of falls, and the ability to perform ADLs and IADLs that are necessary to maintain independence.

Early identification of disability precursors facilitates intervention, and timely detection of events associated with functional decline or limitations--such as falling--can greatly enhance the ability of health-care professionals and informal caregivers to effectively respond. However, there are a number of specific challenges associated with addressing functional decline. Many of these issues involve lack of awareness on the part of older adults, caregivers, and health-care professionals to existing levels of function as well as indicators of clinically meaningful changes in function. For example, older adults are frequently unaware of their level of activity, thereby making it difficult for them to determine if their level of function is declining. Similarly, caregivers of older adults may not notice that an older adult is walking less or with an unstable gait. Other challenges associated with addressing functional decline involve the ability to generate ongoing information that is useful for decision-making. For example, sleep disturbances can be a marker of functional decline, but it can be difficult for a remote caregiver to know that an older adult is experiencing disturbed sleep. Further complicating these issues are challenges associated with ensuring adequate communication among patients, caregivers, and health-care professionals regarding functioning. Finally, monitoring function can be challenging for older adults if the means of generating data requires a high level of engagement on the part of the patient.

8.2. Prevalence of Functional Decline

Many older adults experience limitations in their ability to perform ADLs. In 2007, 25 percent of independently living Medicare recipients reported difficulty with one or more ADLs. This proportion rose to 46 percent among older adults in community housing with services and 83 percent among those in long-term care facilities. An estimated 38 percent of independently living older adults require assistive equipment (such as walking or bathroom aids), 6 percent require personal assistance with ADLs, and 22 percent require both equipment and personal assistance for ADL performance (Federal Interagency Forum on Aging Statistics, 2010). Other data indicate that 38 percent of adults age 65 and older report disabilities in areas such as ambulation and self-care that put them at risk for loss of independence. Moreover, 56 percent of adults age 80 and older report severe disability, and 29 percent report needing help with ADLs (Administration on Aging, 2009). Minority women over 60 are at particularly high risk for physical decline. Compared to their white counterparts, non-white women had poorer lower extremity function, experienced greater difficulty performing ADLs, and were more likely to use assistive walking devices (Ostchega et al., 2000).

Incremental changes in functional decline that lead to more serious impairment are more difficult to ascertain than ADL performance since they can be subtle, and require frequent and detailed assessments that are not part of the standard of care (Rantz et al., 2008). As a result, reliable statistics on antecedent conditions (e.g., gradual declines in activity and mobility) that may predict gross functional decline and eventual loss of independence are limited. Chronic conditions that are causally associated with functional decline occur with high frequency in the U.S. For example, according to the 2007-2009 National Health Interview Survey (NHIS), approximately 50 million adults (22 percent) have been diagnosed with arthritis, a condition that causes gait disorders, reduced mobility, and other functional limitations, and an estimated 21 million people (9 percent) have activity limitations due to this condition (Centers for Disease Control and Prevention, 2011). In turn, gait disorders and mobility limitations are established risk factors for falls because they increase the risk of stumbling, tripping, and the inability to regain stability when balance is lost.

These limitations can be especially serious when they occur in conjunction with other complex, age-associated health issues such as loss of muscle mass, cognitive decline or impairment, poor eyesight, and neuropathy (Alexander and Goldberg, 2005; Menz et al., 2004). Falls, which are discussed in detail in Chapter 1 of this report, often result in hip fractures, which are a leading cause of institutionalization in old age, especially among adults age 80 and older. Growth in the older population and the associated increase in functionally impaired older adults have led to increased demand for technologies that address prevention, detection, and mitigation of functional decline and impairment in this population.

8.3. Cost and Burdens Associated with Functional Decline

Older adults identify good physical functioning as a central factor in maintaining a high quality of life (Webb et al., 2010). Those who rely on others for assistance with the fulfillment of basic needs such as transportation or ADLs, are more socially isolated, have poorer nutrition and exercise habits, and do not receive medical care as often as they need to (Prinz, Cramer, and Englund, 2008). Thus, there are numerous non-financial burdens associated with functional decline and impairment, and these occur with greater frequency as function decreases.

The emotional and monetary burdens of functional decline and impairment on informal caregivers of older adults and others with disabilities are also considerable. In 2007, for instance, it was estimated that informal caregivers provided $375 billion in unpaid health care and support to older adults with ADL or IADL limitations (AARP, 2008). These costs derive from a variety of caregiving elements, including time, transportation, lost wages, and decreased productivity, as well as stress and worry. Long-distance caregivers incur the highest costs ($8,728 in out-of-pocket expenses per year) relative to caregivers who live with an older adult ($5,885 per year) and those who live close by ($4,570 per year) (AARP, 2008). Forty-three percent of caregivers indicate they had no choice but to assume these responsibilities, yet many of them are unprepared to handle caregiver burden on top of their jobs and their own household responsibilities (National Alliance for Caregiving and AARP, 2009). One study found that patients who reported compromised ADLs tended to have caregivers who reported higher caregiving burden, with transportation and financial management predicting the highest levels of burden and, in some cases, strong feelings of resentment (Razani et al., 2007). Studies have also linked caregiving to risk of poverty later in life because caregiving reduces caregivers' earning potential and depletes savings accumulated during their younger years (Wakabayashi and Donato, 2006). Women tend to provide a disproportionate amount of informal caregiving, particularly among minorities, and therefore tend to be disproportionately affected by the burdens associated with caregiving. However, caregiving burdens vary based on a number of factors, including income, age of the caregiver, age of the care recipient, and severity of disability (National Alliance for Caregiving and AARP, 2009).

Estimates of the total health-care spending attributable to functional decline and impairment are significant, particularly among those with chronic diseases as well. According to a study conducted for ASPE, in 2006, an estimated $146 billion was spent on functional limitations among community-dwelling residents (without comorbid chronic diseases); $236 billion was spent on those in need of IADL and ADL assistance; and $268 billion was spent on assistance for other functional deficits. The same report found that functional limitations raise annual health-care costs for adults with chronic conditions, regardless of the number of chronic conditions they suffer from, and regardless of the services they seek (e.g., ER, prescriptions, inpatient, home health services) (Lewin, 2010). Average annual health-care costs for older adults whose functioning has declined to the point where nursing-home care is needed are considerably higher than those for their independently living counterparts ($57,022 vs. $12,383 per person per year).

Some older adults turn to long-term care insurance to cover a portion of these expenses, but the cost of these policies is rising rapidly suggesting that they will soon become unaffordable for an even larger share of those who could benefit from them (Kaiser Commission on Medicaid and the Uninsured, 2006). While those who do not have financial assets depend on Medicaid from the outset, the majority simply pay out-of-pocket for skilled nursing care or assisted-living facilities until they exhaust their financial resources and transition to a Medicaid-covered facility. Future limitations on access to long-term care may be due to a combination of increases in the cost of services and coverage, the aging of the population, and the growing demand for health-care services that will place an unprecedented strain on Medicare, Medicaid, and health-care providers. These factors will ensure that controlling costs while providing high-quality care will become an even higher health-care priority that will require especially innovative solutions (Crossen-Sills, Toomey, and Doherty, 2009). Indeed, because of the significant costs associated with long-term care relative to independent living, the extent to which transitions can be avoided or delayed presents significant opportunities for cost savings (Federal Interagency Forum on Aging-Related Statistics, 2010). Technologies that target functional decline and impairment are one strategy to address these opportunities.

8.4. Available Functional Assessment and Assistive Technologies and Evidence of Their Benefits

Numerous technologies aimed at assessment of physical activity, wellness, gait, and balance, as well as ADL and IADL performance, are currently available (Center for Aging Services Technology, 2007). Some devices exclusively target older adults and individuals with disabilities, while others provide support to both caregivers and care recipients. The latter devices seek to facilitate communication, increase shared knowledge, and define and implement holistic care plans.

Declines in overall physical activity levels and generalized wellness can signal functional decline or impairment. A variety of technologies are available to monitor activity levels. Some of these devices are worn by the user to detect events such as falls, some are embedded in the user's environment to track complex activity patterns, and others are wearable devices aimed at measuring and promoting physical activity. These technologies serve a diversity of functions ranging from encouraging exercise to complex assessments of gait, balance, and sleep patterns (Zhang et al., 2003).

Wearable Devices

A number of monitoring technologies can be worn by the user. Examples of data collected by these devices include time spent engaged in physical activity (Zhang et al., 2003), energy expenditure (Zhang, Pi-Sunyer, and Boozer, 2004), and gait (Huddleston et al., 2006). Advances in these technologies have resulted in the availability of very small sensors that can be applied in a variety of ways. For example, they can be embedded in special clothing such as shirts (Lee and Chung, 2009) and vests (Pandian et al., 2008), and they can be embedded in straps that are worn on the chest, waist, or arms (Pruitt et al., 2008). Once identified, information from these devices can serve as a resource for risk assessment and rehabilitative interventions to improve factors such as strength and mobility. Some wearable technologies use multiple sensors placed across the body for detailed gait, balance, and activity assessments (e.g., Intelligent Device for Energy Expenditure). However, these technologies can be cumbersome to wear for the extended periods of time that are necessary to allow continuous assessment. Other, less sophisticated wearable activity monitors offer continuous data collection at relatively low cost and can provide a means for continuous assessments that would otherwise require frequent office visits. In some cases, these technologies can also serve as part of intervention strategies such as encouraging physical activity to reduce the risk of falling (Landi et al., 2007). They can also provide feedback to users, their family members, and health-care professionals (LeadingAge CAST, 2007). At least 11 reports have described the strengths and limitations of these wireless systems and most have concluded that sensors perform well in accurately measuring older adults' activity (Murphy, 2009). However, it is also important to note that these technologies have yet to be proven effective in reducing negative health consequences such as falls or in mitigating functional decline and impairment.

Some wearable activity-monitoring technologies focus specifically on promotion of wellness-oriented behaviors that inhibit functional decline and impairment such as exercise and weight loss. These technologies encourage users to increase their activity levels by providing timely feedback and cueing, and allow the integration of wearable devices with online platforms and wellness communities. For example, these technologies can serve as weight-management tools by measuring energy expenditure and activity levels, body mass index (BMI), and caloric intake (Murphy, 2009). The data from these devices can be transferred to an online platform where users can monitor their weight loss and activity levels and communicate with an online community. For individuals who are mobile, but need to engage in ongoing self-management, these devices allow users to become active partners in their own health and wellness activities in a manner that inhibits functional decline and impairment (Richardson, 2010). For healthy, aging adults, these technologies can encourage activity and maintenance of mobility. For frail and at-risk individuals, the devices can encourage sufficient activity to preserve or improve existing levels of function.

One study found that participants who wore activity monitors as part of a physical activity program were more active at a six-month follow up than control groups, and were just as active as participants who received telephone-based counseling. At a 12-

month follow up, the activity-monitoring and control groups were equally active, whereas the telephone group maintained higher levels of activity (Napolitano et al., 2010). This suggests that monitors were effective in promoting short-term behavior change, but were not sufficient in isolation to support long-term behavior change. Further research may improve our understanding of how best to use monitors, possibly in combination with other forms of support, to sustain long-term behavioral change favoring increased activity.

Obesity is a predictor of functional decline and impairment and another parameter that activity-monitoring technologies specifically target. One study used activity monitors to measure caloric intake, physical activity levels, and energy expenditures in a group of diabetes patients participating in a 12-week exercise intervention. Although participants lost weight, the lack of a control group creates challenges for interpreting these findings (Jung et al., 2010). However, another study using activity monitors demonstrated an inverse relationship between daily steps and risk factors that are predictive of long-term risk for cardiac events. These results suggest that physical activity monitoring may help assess risk for pathology and/or chronic disease that threaten independence, thereby allowing interventions to be implemented (Sisson et al., 2010). These studies provide support for the idea that physical activity monitoring may be useful among relatively healthy adults (Jakicic et al., 2010).

In the event of an emergency, many wearable monitoring systems are designed to alert caregivers via wireless networks, email, or text, and some systems can alert an emergency call center. These systems often focus on falling, but some also incorporate electrocardiographic sensors and detect cardiac events (Pandian et al., 2008). Some wearable fall detectors have automated fall detection capability that can replace call buttons and require no action on the part of the user. Others are pendants worn around the neck or wrist and require the user to activate the alarm in the event of a fall or other medical emergency (Roberts and Mort, 2009). Chapter 1 of this report explores these technologies in greater detail in relation to falls.

Passive Monitoring Systems

Passive in-home monitoring systems consist of sensors that are installed or embedded in the user's living environment and collect information without active input or engagement on the part of the user. These systems typically have motion sensors as well as other environmental sensors (e.g., temperature, humidity, and contact) that are strategically placed in various settings, including the home, assisted-living facilities, nursing homes, and hospitals. These systems can detect movements and movement-related parameters such as gait and balance, and other indicators of routine activities such as cooking and bathroom use. Based on data collected during a calibration period, these systems can “learn” a user's routine and use this information to infer whether observed periods of heightened activity or marked inactivity are benign or suggestive of outcomes such as a decline in function, acute illness, or a fall (Virone, 2009). For example, sensors in and around the kitchen can record movements and activities related to meal preparation, such as opening and closing the refrigerator, using the stove, or movements near the sink while cleaning dishes (Glascock and Kutzik, 2006). Food preparation is an IADL for which decreased activity might indicate a decline in mobility, disease, or depression, all of which can signal a decline in global function. Research suggests that these systems are capable of inferring these activities with a high degree of accuracy (Dalal et al., 2005).

These systems also have the ability to detect potentially dangerous situations such as falls through motion sensors, cameras, vibration sensors on the floor, or a combination of these technologies (Stone et al., 2009). Further, these passive-monitoring systems can be linked to online platforms that generate and transmit alerts to a family member, neighbor, or call center. Clinicians and family members can also monitor this information online to observe activity patterns and to ensure that care is delivered quickly (Alwan et al., 2006).

Unlike wearable devices, passive systems have the advantage of blending into the environment and are therefore not dependent on user compliance. Glascock and Kutzik reviewed the evolution of passive-monitoring devices and a variety of their features. They also conducted a two-city field test, installing motion sensors in the homes of older adults to passively monitor waking time, falls, overnight bathroom use, medication compliance, meal preparation, and global activity. In that study, the passive device had 98 percent reliability for detection and recording of events and successfully transmitting data to a website for review. A series of case studies evaluating caregiver “action” after receiving a monitoring alert demonstrated the efficacy of passive monitoring. In each case, a nurse monitor was able to intervene early and act on clinically relevant information in a manner that would have not been possible had the system not provided the relevant data (Glascock and Kutzik, 2006).

Another report assessed the psychosocial impact of passive monitoring on patients and caregivers. During the four months of this study, neither patients nor caregivers reported significant changes in quality of life. Although the number of hours of caregiving increased, there was no reported increase in caregiver strain. This study suggests that this technology led family caregivers to become more engaged in the care process in ways that did not increase their perceived burden. The same study also offers a window into the potential of these technologies to “predict” acute events. Several patients experienced unfavorable changes in functional status in the days immediately prior to hospitalization, suggesting that passive-monitoring technologies detect the types of changes that in some cases may be used to intervene to prevent or, at a minimum, lower the likelihood of costly transitions to higher levels of care through crisis avoidance (Alwan et al., 2006).

Monthly monitoring fees and related expenses vary among passive activity-monitoring systems. However, these costs can be offset by the cost savings associated with avoiding or minimizing unplanned doctor visits, laboratory tests, and hospital stays (Glascock and Kutzik, 2006). One study demonstrated the costs and benefits of passive monitoring in a three-month study at three assisted-living facilities (Alwan et al., 2007b). Monitored participants required fewer ER visits and fewer hospital days than unmonitored ones and incurred significantly lower health-care costs for billable services: $17,407.02 for monitored participants, including monitoring costs, compared to $67,753.88 for unmonitored controls (Alwan et al., 2007b). A recent white paper discussed the benefits of another in-home passive activity-monitoring technology in a Philadelphia PACE (Program for All-Inclusive Care of the Elderly) Program. The program combined daytime remote monitoring with intermittent care and provided a supportive, but less expensive alternative to nursing-home admission. This report serves as additional evidence of potential cost savings associated with passive-monitoring technologies among older adults with functional decline or impairment (Business Wire, 2010).

Devices for Sleep Monitoring

Sleep disturbances have profound implications for global health and wellness and are a common symptom of obstructive sleep apnea (Patel, Alexander, and Davidson, 2007). Sleep apnea, in turn, is a risk factor for a number of conditions that can have a substantial impact on health, and ultimately, functional status. Sleep apnea is a risk factor for cardiovascular disease (Gottlieb et al., 2010), hypertension (O'Connor et al., 2009), stroke (Redline et al., 2010), and diabetes (Punjabi et al., 2004), all of which can be fatal (Punjabi et al., 2009). Sleep disturbances can also lead to daytime fatigue (Chartier-Kastler and Davidson, 2007), which in turn elevates the risk of falls, vehicular accidents, compromised immune function, and lower quality of life (Schneider and Stanley, 2007). Sleep-monitoring technologies seek to provide early detection and monitoring of sleep disturbances so that the impact of these disturbances on function is minimal.

Sleep disturbances can be detected with passive sleep-monitoring systems, thereby enabling caregivers to intervene and prevent more serious outcomes (Tyrer et al., 2007). These systems offer effective approaches for early detection of sleep disturbances that are integrated into the user's environment (Mack et al., 2009). Other approaches to sleep monitoring require a higher level of engagement on the part of the user. For example, actigraphy is a sleep-monitoring technique that employs an accelerometer similar to those used in wearable activity-monitoring devices. The device is worn overnight on the wrist, and distinguishes between periods of sleep and wakefulness based on wrist movements. One significant limitation of this technology is that it cannot distinguish restless sleep from restless wakefulness (Jean-Louis et al., 2001). It tends to over-estimate sleep periods when an individual who is awake lies in bed with minimal or no motion; it is also unable to identify restful rapid eye movement (REM) sleep or episodes of apnea (Mack et al., 2006). On the other hand, actigraphy provides a low-cost, home-based alternative to polysomnography, a traditional and costly sleep assessment that is most often conducted in a sleep clinic or hospital setting (Ayas et al., 2010).

Ballistocardiography, which measures ballistic forces on the heart through pressure sensors, is emerging as a sleep assessment that uses passive monitoring to overcome non-compliance issues associated with actigraphy. These devices monitor physiological changes during sleep, as well as sleep disturbances, with minimal disruption to the user's environment (Mack et al., 2006). For example, one ballistocardiographic system in particular uses foam bed pads placed between the sheets and mattress. The pads connect to pressure sensors that detect changes in the air pressure in response to cardiac, respiratory, and musculoskeletal movement. Not only are these devices better suited to the home environment than is actigraphy, but clinical trials have shown they are as accurate as electrocardiographic equipment for measuring cardiac parameters and are superior to actigraphy in detecting sleep onset (Mack et al., 2009a).

Load cells are another passive home sleep device that are both easy to deploy and unobtrusive to the user. Placed at the corners of a bed under the bedposts, load cells measure changes in force, or "load," associated with the user's movement in bed (Adami et al., 2010). These cells distinguish different movements and record the time intervals in which they occur. They can also detect physiological data, such as heart rate and respiration, thereby permitting monitoring of sleep disturbances associated with cardiac events and sleep apnea (Adami, 2006). Investigators are currently exploring load cells as an alternative to existing lab-based sleep-monitoring systems, such as polysomnography (Beattie et al., 2009).

Interactive communication

Another approach to assessing older adults' overall levels of wellness and function is through interactive communications devices. These devices are designed to allow patients, family members, and physicians to share data, but they also permit these stakeholders to interact in ways that facilitate improved care coordination. The devices present the user with a series of wellness questions such as how they are feeling, how well they slept the previous night, their mood, their ability to perform ADLs, and their compliance with medication usage. These interactive platforms can play an important role in overall function by strengthening users' awareness of their functional status. Data are transmitted to a family or professional caregiver who can call and follow up with the user to help with self-management skills, provide informal care, or arrange for supportive services.

Several interactive wellness systems have emerged to facilitate the exchange of health and wellness information among individuals, families, and caregivers. While these systems do not involve physiological monitoring, they do attempt to improve wellness checks and health management, as well as support independence using convenient and more frequent communication with caregivers. Features of these systems may include medication reminders, online journals to track diet, medication, and exercise, and a web portal for health-care professionals and patients to review data and interact with one another. While some of these systems are mobile, others are based on touch-screen home computers with interfaces that are easy for older adults to use (RAND, 2000). Current evidence supporting the benefits of these platforms is modest. One study evaluated the effectiveness of an interactive wellness system that allows diabetes patients to answer daily health questionnaires through a desktop application. The information is automatically transferred to a case manager who reviews the data and contacts a physician if symptoms warrant clinical intervention. Patients reported improved quality of life and reduced need for services (inpatient, ER visits, post-discharge and outpatient visits), as well as small improvements in physical health assessments (Cherry et al., 2002). Overall, research on use of these systems for maintaining functional abilities is encouraging, but not definitive.

8.5. Functional Assessment and Assistive Technologies Under Development

A number of technologies that are under development address various aspects of functional decline and impairment, ranging from new approaches to detection of subtle changes in gait and balance to complex systems that integrate multiple data streams from the home in order to identify declining function. Functional decline and impairment are closely associated with increased incidence of falls; as such, technologies that help detect and prevent falls also assist in mitigating functional decline and impairment.

Older adults frequently experience reduced sensation in their extremities, often related to neuropathy or neuropathic complications from diabetes. Loss of sensation in the feet in particular is associated with poor balance, slower and irregular gait, and increased fall risk (Priplata et al., 2006), all of which reduce older adults' ability to remain active and thus increase the risk of functional decline and impairment. A pressure-sensitive shoe insole is one device that is being developed to identify balance problems indicative or predictive of functional decline. Sensors embedded in the insoles of shoes measure pressure distribution across the foot. This device will be used to identify balance problems that may indicate functional decline or worsening impairment. In addition to identifying data patterns that may indicate balance difficulties, the functionality of this device may be expanded to include the transmission of alerts in response to foot pressure patterns that indicate the user is experiencing difficulty walking (Trafton, 2006).

Similarly, researchers have begun testing insoles that deliver vibrations to the foot to stimulate nerves and heighten sensation. In one study, these vibrations reduced body sway and increased balance and steadiness in older adults (Priplata et al., 2003). Another group showed that impulse-generating insoles worn while walking reduced gait variability in older adults regardless of their experience with falls, suggesting that this technology may have applications for improving steadiness among people with a history of falling and known functional decline (Galica et al., 2009). Another group is developing a wireless device that analyzes step patterns, speed, and foot positioning. This device, which straps to the ankle and can be worn with any footwear without interfering with normal walking, wirelessly relays information to laboratory-based computers. Data are analyzed to identify factors related to gait disorders and functional decline, such as poor balance, heel strike timing, and variations in walking speed that can be used to inform clinical interventions (e.g., targeted exercise regimes or physical therapy) (Bamberg et al., 2008).

In addition to currently available, wearable technologies, emerging technologies that are embedded in the user's environment are being developed to monitor key parameters associated with functional decline and detect changes in ability and/or emerging impairment. Many of these technologies target issues associated with walking and balance. For example, one technology employs portable gait mats containing sensors that enable researchers and clinicians to detect, analyze, and intervene when evidence of gait abnormalities are detected that are indicative of both functional decline and fall risk. These mats record each footfall as users walk across the sensors, and data are transmitted wirelessly to a computer for analysis. They also measure information such as stride length, timing, and pressure distribution across the foot and detect high-risk patterns. These devices can replace labor-intensive paper and pencil methods (such as chalking or inking the feet, video recording, and hand-timing of strides), thereby eliminating not only the measurement errors associated with these methods but also the need for a trained professional to observe the older adult for risk assessment (McDonough et al., 2001). The devices have been validated for use in functional decline and also fall risk assessment (Low, Tani, and Chandra, 2009).

Passive infra-red (PIR) sensing is another example of a gait assessment method that is used in the home. This technology employs an array of narrow-band infra-red sensors that are arranged on walls or ceilings to detect movement. These sensors can measure relevant factors such as walking speed and they can also distinguish “typical” and “atypical” movements in a manner that might indicate functional decline and that may not be readily detected in a clinical setting but are evident in the course of daily activities in the home. These PIRs have been shown to estimate walking speed more accurately than standard clinical timed walking tests (Hayes et al., 2009) and they measured walking speeds as accurately as gait mats (Hagler et al., 2010).

Many older adults use aids such as walkers and canes to assist with ambulation, making these "low-tech" aids an appealing target for technology enhancement. A few groups are currently exploring how to engineer these common aids to serve as both assistive devices and gait-assessment tools. One technology involves embedding force sensors in the handles of “smart walkers” and combining them with wheel-based odometers. This walker can passively monitor parameters such as stride time, step and stride length, and walking speed. Thus far, studies of this device have been restricted to the lab, but as these technologies are fine-tuned, they could be adapted for passive monitoring in the home to evaluate gait, balance, and mobility during routine activity (Alwan et al., 2007a). Such a walker could also be engineered to actively assist users' movements by, for example, helping those with visual impairments avoid obstacles (Alwan et al., 2005).

Ambient intelligence is an emerging field that combines the sensor-based technologies discussed in this chapter such as sleep and passive physiological monitoring devices with “sensitivity” to the environment and users' needs (Intille, 2005). Ambient intelligence relies on sensory input from the home environment, such as information on motion, light, temperature, radiation, sound, and walking or standing pressure, as well as physiologic data that are collected from the user. The combination of these diverse information streams makes it possible to profile the user's home, thereby enabling the device to make adjustments in response to the user's presence and preferences, and also to detect or avert emergencies. For example, a kitchen stove left unattended for a specified period of time would set off an alarm. An unanswered doorbell when the user is at home and not hearing-impaired might trigger an emergency call. This technology must address a number of practical challenges, such as distinguishing the user from a guest in his or her home. One solution currently in development is a small wearable tracking "button" that alerts the system to the resident's presence in a particular room (Cook, Augusto, and Jakkula, 2009). A number of research teams are working on refining such adaptive technology networks (Rantz et al., 2008; Kaye and Hayes, 2006).

8.6. Experiences of Other Countries with Functional Decline Assessment and Assistive Technologies

International efforts to develop, validate, and promote the use of assistive technologies in the home are widespread and for the most part similar to efforts in the U.S. However, several unique technologies under development internationally focus on assisted walking. In Israel, a battery-operated robotic suit is being developed to enable individuals with lower-limb disability or paralysis to walk. The suit uses a combination of sensors that detect upper-body movement, body braces with motorized leg joints, crutches, and a small computer to process incoming data and control the suit's motors. Although developers have initiated a device safety trial and plan a clinical trial, the results have not yet been published. However, preliminary data show that users are able to sit, stand, and ambulate safely and independently with the device.

Japan has a similar robotic suit in production. This full-body suit is designed to aid and potentially rehabilitate individuals with limited mobility. It consists of robotic supports that attach to the arms, legs, and torso, depending on the user's needs. When the user initiates a movement, the brain sends nerve signals that cause muscles to contract. These signals generate electrical impulses on the surface of the skin. The robotic suit monitors and responds to these impulses by moving the assistive limbs in coordination with the body. The assisted motion combined with the suit's ability to reduce the physical load on the user's muscles augments the user's strength, and increases mobility (Zelinsky, 2009). This robotic suit, like the Israeli one, has the potential to improve mobility in older adults and therefore support independent living.

Work on social alarms (Empirica and World Research Centre, 2010), wearable ambulatory devices (Liu, Inoue, and Shibata, 2009), physiological monitors (Lai et al., 2009), home telecare (Nikus et al., 2009), telehealth (Koch and Hagglund, 2009), and smart home technologies (Friedewald et al., 2005) is abundant and similar to that being conducted in the U.S. However, other countries have made greater strides in adoption and integration of certain technologies into their health-care systems (Empirica and World Research Centre, 2010). Finland has also received recognition for the integration and widespread use of wrist-worn alarms and for initial exploration of video-based telecare services. Germany and Sweden have developed video-telecare systems, although they are not widely used. Germany has enacted policies that better integrate these technologies into health-care provision and integration structures that have promoted the use of such technologies (Empirica and World Research Centre, 2010). In general, however, the EU's increasing interest in ambient assistive technologies has spawned research and development activities, but there has been little integration into the social care system.

References

AARP (2008). Valuing the invaluable: The economic value of family caregiving, 2008 update. http://assets.aarp.org/rgcenter/il/i13_caregiving.pdf. Accessed April 4, 2012.

Adami, A.M., Pavel, M., Hayes, T.L., Singer, C.M. (2010). Detection of movement in bed using unobtrusive load cell sensors. *Institute of Electrical and Electronics Engineers Transactions on Information Technology in Biomedicine*, 14(2), 481-490.

Administration on Aging (2009). A profile of older Americans: 2009. Washington, D.C.: U.S. Department of Health and Human Services. http://www.aoa.gov/aoaroot/aging_statistics/profile/2009/docs/2009profile_508.pdf. Accessed April 4, 2012.

Alexander, N.B., Goldberg, A. (2005). Gait disorders: Search for multiple causes. *Cleveland Clinic Journal of Medicine,* 72(7), 586, 589-90.

Alwan M., Leachtenauer J., Dalal S., Mack D., Kell S., Turner B., Felder R. (2006). Psychosocial impact of passive health status monitoring on informal caregivers and older adults living in independent senior housing. 2nd Institute of Electrical and Electronics Engineers Conference on Information & Communication Technologies: From Theory to Applications, 808-813.

Alwan M., Ledoux, A. Wasson, G., Sheth, P., Huang, C. (2007a). Basic walker-assisted gait characteristics derived from forces and movements exerted on the walker's handles: Results on normal subjects. *Journal of Medical Engineering and Physics*, 29(3), 380-389.

Alwan, M., Rajendran, P.J., Ledoux, A., Huang, C., Wasson, G., Sheth, P. (2005). Stability margin monitoring in steering-controlled intelligent walkers for the elderly. 21st Annual Association for the Advancement of Artificial Intelligence Fall Symposium.

Alwan, M., Sifferlin, E.B., Turner, B., Kell, S., Brower, P., Mack, D.C., Dalal, S., Felder, R. (2007b). Impact of Passive Health Status Monitoring to Care Providers and Payers in Assisted Living. Journal of Telemedicine and E-Health, 13(3), 279-286.

Ayas, N.T., Fox, J., Epstein, L., Ryan, C.F., Fleetham, J.A. (2010). Initial use of portable monitoring versus polysomnography to confirm obstructive sleep apnea in symptomatic patients: An economic decision model. Sleep Medicine, 11(3), 320-324.

Bamberg, S.J., Benbasat, A.Y., Scarborough, D.M., Krebs, D.E., Paradiso, J.A. (2008). Gait analysis using a shoe-integrated wireless sensor system. *IEEE Transactions on Information Technology in Biomedicine,* 12(4), 413-423.

Beattie, Z.T., Hagen, C.C., Pavel, M., Hayes, T.L. (2009). Classification of breathing events using load cells under the bed. 31st Annual International Conference of the Institute of Electrical and Electronics Engineers, Engineering in Medicine and Biology Society, 3921-3924.

Business Wire (2010). New study finds remote monitoring technology enables the elderly to remain independent longer, reduces care costs for providers. Business Wire. http://www.businesswire.com/news/home/20100929005411/en/Study-Finds-Remote-Monitoring-Technology-Enables_Elderly. Accessed April 4, 2012.

Centers for Disease Control and Prevention (2011). Arthritis: Data and statistics. Atlanta, G.A.: U.S. Department of Health and Human Services. http://www.cdc.gov/arthritis/data_statistics.htm. Accessed April 4, 2012.

Chartier-Kastler, E. Davidson, K. (2007). Evaluation of quality of life and quality of sleep in clinical practice. *European Urology Supplements,* 172(1), 311-316.

Cherry, J.C., Moffatt, T.P., Rodriguez, C., Dryden, K. (2002). Diabetes disease management program for an indigent population empowered by telemedicine technology. *Diabetes Technology and Therapeutics,* 4(6), 783-791.

Cook, D.J., Augusto, J.C., Jakkula, V.R. (2009). Ambient intelligence: Technologies, applications, and opportunities. *Pervasive and Mobile Computing,* 5(4), 277-298.

Crossen-Sills, J., Toomey, I., Doherty, M.E. (2009). Technology and home care: Implementing systems to enhance aging in place. *Nursing Clinics of North America,* 44(2), 239-246.

Dalal, S., Alwan, M., Seifrafi, R., Kell, S., Brown, D. (2005). A rule-based approach to analyzing elders' activity data: Detection of health and emergency conditions. 20th Annual National Conference on Artificial Intelligence, Association for the Advancement of Artificial Intelligence, 3290-3293.

Empirica and World Research Centre on behalf of the European Commission, Directorate General for Information Society and Media (2010). ICT & Ageing: European Study on Users, Markets and Technologies. http://ec.europa.eu/information_society/activities/einclusion/library/studies/docs/ict_ageing_final_report.pdf. Accessed April 4, 2012.

Federal Interagency Forum on Aging-Related Statistics (2010). Older Americans 2010: Key indicators of well being. Hyattsville, M.D.: National Center for Health Statistics. http://www.agingstats.gov/agingstatsdotnet/Main_Site/Data/2010_Documents/Docs/OA_2010.pdf.

Friedewald, M., Da Costa, O., Punie, Y., Alahuhta, P., Heinonen, S. (2005). Perspectives of ambient intelligence in the home environment. *Telematics and Informatics*, 22(3), 221-238.

Gammack, J.K. (2010). Lower urinary tract symptoms. *Clinics in Geriatric Medicine,* 26(2), 249-260.

Glascock, A., Kutzik, D. (2006). The impact of behavioral monitoring technology on the provision of health care in the home. *Journal of Universal Computer Science,* 12(1), 59-72.

Gottlieb, D.J., Yenokyan, G., Newman, A.B., O'Connor, G.T., Punjabi, N.M., Quan, S.F., Redline, S., Resnick, H.E., Tong, E.K., Diener-West, M., Shahar, E. (2010). Prospective study of obstructive sleep apnea and incident coronary heart disease and heart failure: The Sleep Heart Health Study. *Circulation,* 122(4), 352-360.

Hagler, S., Austin, D., Hayes, T.L., Kaye, J., Pavel, M. (2010). Unobtrusive and ubiquitous in-home monitoring: A methodology for continuous assessment of gait velocity in elders. *IEEE Transactions on Biomedical Engineering,* 57(4), 813-820.

Hayes, T.L., Hagler, S., Austin, D., Kaye, J., Pavel, M. (2009). Unobtrusive assessment of walking speed in the home using inexpensive PIR sensors. 31st Annual International Conference of the Institute for Electrical and Electronics Engineers, Engineering in Medicine and Biology Society, 7248-7251.

Huddleston, J., Alaiti, A., Goldvasser, D., Scarborough, D., Freiberg, A., Rubash, H., Malchau, H., Harris, W., Krebs, D. (2006). Ambulatory measurement of knee motion and physical activity. Preliminary evaluation of a smart activity monitor. *Journal of NeuroEngineering and Rehabilitation,* 13(3), 1-10.

Intille, S.S. (2005). The goal: Smart people, not smart homes. Proceedings of the 3rd International Conference on Smart Homes and Health Telematic.

Jakicic, J.M., Davis, K.K., Garcia, D.O., Verba, S., Pellegrini, C. (2010). Objective monitoring of physical activity in overweight and obese populations. *Physical Therapy Reviews,* 15(3), 163-169.

Jean-Louis, G., Kripke, D.F., Cole, R.J., Assmus, J.D., Langer. R.D. (2001). Sleep detection with an accelerometer actigraph: comparisons with polysomnography. *Physiology and Behavior,* 72(1-2)*,* 21-28.

Jung , J.Y., Han, K.A., Kwon, H.R., Ahn, H.J., Lee, J.H., Park, K.S., Min, K.W. (2010). The usefulness of an accelerometer for monitoring total energy expenditure and its clinical application for predicting body weight changes in type 2 diabetic Korean women. *Korean Diabetes Journal,* 34(6), 374-383.

Kaiser Commission on Medicaid and the Uninsured (2006). Frontline perspectives on long-term care financing decisions and Medicaid assets transfer practices. http://www.kff.org/medicaid/upload/7458.pdf. Accessed April 4, 2012.

Katz, S., Ford, A.B., Moskowitz, R.W., Jackson, B.A., Jaffe, M.W. (1963). "The index of ADL: A standardized measure of biological and psychosocial function. *Journal of the American Medical Association*, 185(12), 914-919.

Kaye, J.A., Hayes, T.L. (2006). Home health monitoring: A system to assess motor and cognitive function. *Generations,* 30(2), 61-63.

Koch, S., and Hägglund, M. (2009). Health informatics and the delivery of care to older people. *Maturitas,* 63(3), 195-199.

Lai, C.C., Lee, R.G., Hsiao, C.C., Liu, H.S., Chen, C.C. (2009). A H-QoS-demand personalized home physiological monitoring system over a wireless multi-hop relay network for mobile home healthcare applications. *Journal of Network and Computer Applications,* 32(6), 1229-1241.

Landi, F., Onder, G., Carpenter, I., Cesari, M., Soldata, M., Bernabei, R. (2007). Physical activity prevented functional decline among frail community-living elderly subjects in an international observational study. *Journal of Clinical Epidemiology,* 60(5), 518-524.

Lawton, M.P., Brody, E.M. (1969). Assessment of older people: Self-maintaining and instrumental activities of daily living. *Gerontologist,* 9(3), 179-186.

LeadingAge CAST (2007). State of technology in aging services. http://www.leadingage.org/uploadedFiles/Content/About/CAST/Resources/State_of_Technology_Report.pdf. Accessed February 16, 2012.

Lee, Y.D., Chung, W.Y. (2009). Wireless sensor network based wearable smart shirt for ubiquitous health and activity monitoring. *Sensors and Actuators B: Chemical,* 140(2), 390-395.

Lewin Group, The (2010). Individuals living in the community with chronic conditions and functional limitations: A closer look. Assistant Secretary for Planning and Evaluation. Washington, D.C.: U.S. Department of Health and Human Services. http://aspe.hhs.gov/daltcp/reports/2010/closerlook.htm.

Liu, T., Inoue, Y., Shibata, K. (2009). Development of a wearable sensor system for quantitative gait analysis. *Measurement*, 42(7), 978-988.

Low, K.H., Tani, J.W., Chandra, T. (2009). Initial home-based foot-mat design and analysis of bio-gait characteristics to prevent fall in elderly people. Annual Institute of Electrical and Electronics Engineers International Conference on Robotics and Biomimetics, 759.

Mack, D.C., Alwan, M., Turner, B., Suratt, P., Felder, R.A. (2006). A passive and portable system for monitoring heart rate and detecting sleep apnea and arousals: Preliminary validation. Proceedings of the 1st Transdisciplinary Conference on Distributed Diagnosis and Home Healthcare, 51-54.

Mack, D.C., Patrie, J.T., Felder, R.A., Suratt, P.M., Alwan, M. (2009). Sleep assessment using a passive ballistocardiography-based system: Preliminary validation. 31st Annual International Conference of the Institute of Electrical and Electronics Engineers, Engineering in Medicine and Biology Society, 4319-4322.

Mack, D.C., Patrie, J.T., Suratt, P.M., Felder, R.A., Alwan, M. (2009a). Development and preliminary validation of heart rate and breathing rate detection using a passive, ballistocardiography-based sleep monitoring system. *IEEE Transactions on Information Technology in Biodmedicine,* 13(1), 111-120.

McDonough, A.L., Batavia, M., Chen, F.C., Kwon, S., Ziai, J. (2001). The validity and reliability of the GAITRite system's measurements: A preliminary evaluation. *Archives of Physical Medicine and Rehabilitation*, 82(3), 419-425.

Menz, H.B., Lord, S.R., St. George, R., Fitzpatrick. R.C. (2004). Walking stability and sensorimotor function in older people with diabetic neuropathy. *Archives of Physical Medicine and Rehabilitation*, 85(2), 245-252.

Murphy, S.L. (2009). Review of physical activity measurement using accelerometers in older adults: Considerations for research design and conduct. *Preventive Medicine,* 48(2), 108-114.

Napolitano, M.A., Borradaile, K.E., Lewis, B.A., Whiteley, J.A., Longval, J.L., Parisi, A.F., Albrecht , A.E., Sciamanna, C.N., Jakicic, J.M., Papandonatos, G.D., Marcus, B.H. (2010). Accelerometer use in a physical activity intervention trial. *Contemporary Clinical Trials,* 31(6), 514-523.

National Academy on an Aging Society (1999). Challenges for the 21st century: chronic and disabling conditions. http://www.agingsociety.org/agingsociety/pdf/chronic.pdf. Accessed April 4, 2012.

National Alliance for Caregiving and AARP (2009). Caregiving in the U.S.: A focused look at those caring for someone age 50 or older. http://www.caregiving.org/data/FINALRegularExSum50plus.pdf. Accessed April 4, 2012.

Nikus K, Lahteenmake, J., Lehto, P., Eskola, M. (2009). The role of continuous monitoring in a 24/7 telecardiology consultation service- a feasibility study. *Journal of Electrocardiology,* 42(6), 473-480.

O'Connor, G.T., Caffo, B., Newman, A.B., Quan, S.F., Rapoport, D.M., Redline, S., Resnick, H.E., Samet, J., Shahar, E. (2009). Prospective study of sleep-disordered breathing and hypertension: The sleep heart health study. *American Journal of Respiratory and Critical Care Medicine,* 179(12), 1159-64.

Ostchega, Y., Harris, T.B., Hirsch, R., Parsons, V.L., Kington, R. (2000). The prevalence of functional limitations and disability in older persons in the U.S.: Data from the national health and nutrition examination survey III. *The Journal of the American Geriatrics Society,* 48(9), 1132-1135.

Pandian, P.S., Mohanavelu, K., Safeer, K.P., Kotresh, T.M., Shakunthala, D.T., Gopal, P., Padaki, V.C. (2008). Smart Vest: Wearable multi-parameter remote physiological monitoring system. *Medical Engineering and Physics,* 30(4), 466-477.

Patel, M.R., Alexander, T.H., Davidson, T.M. (2007). Home sleep testing. *Operative Techniques in Otolaryngology-Head and Neck Surgery,* 18(1), 33-51.

Prinz, L., Cramer, M., Englund, A. (2008). Telehealth: A policy analysis for quality, impact on patient outcomes, and political feasibility. *Nursing Outlook,* 56(4), 152-158.

Priplata, A.A., Niemi, J.B., Harry, J.D., Lipsitz, L.A., Collins, J.J. (2003). Vibrating insoles and balance control in elderly people. *Lancet,* 362(9390), 1123-1124.

Priplata, A.A., Patritti, B.L., Niemi, J.B., Hughes, R., Gravelle, D.C., Lipsitz, L.A., Veves, A., Stein, J., Bonato, P., Collins, J.J. (2006). Noise-enhanced balance control in patients with diabetes and patients with stroke. *Annals of Neurology,* 59(1), 4-12.

Pruitt, L.A., Glynn, N.W., King, A.C., Guralnik, J.M., Aiken, E.K., Miller, G., Haskell, W.L. (2008). Use of accelerometry to measure physical activity in older adults at risk for mobility disability. *Journal of Aging and Physical Activity,* 16(4), 416-434.

Punjabi, N.M., Caffo, B.S., Goodwin, J.L., Gottlieb, D.J., Newman, A.B., O'Connor, G.T., Rapoport, D.M., Redline, S., Resnick, H.E., Robbins, J.A., Shahar, E., Unruh, M.L., Samet, J.M. (2009). Sleep-disordered breathing and mortality: A prospective cohort study. *Postgraduate Medicine,* 121(6), 197-199.

Punjabi, N.M., Shahar, E., Redline, S., Gottlieb, D.J. Givelber, R., Resnick, H.E. (2004). Sleep-disordered breathing, glucose intolerance, and insulin resistance: The sleep heart health study. *American Journal of Epidemiology,* 160(6), 521-530.

RAND (2000). Patient compliance with and attitudes towards Health Buddy™. http://www.rand.org/content/dam/rand/pubs/monograph_reports/2007/MR1232.pdf. Accessed April 4, 2012.

Rantz, M., Skubic, M., Burks, K., Demiris, G., Hensel, B.K., Alexander, G.L., He, Z., Tyrer, H.W., Hamilton, M., Lee J., Brown, M. (2008). Functional Assessment and Technology. In M. Alwan, R. A. Felder, *Eldercare Technology for Clinical Practitioners*, 5-32. Totowa, NJ: Humana Press.

Razani, J., Kakos, B., Orieta-Baralace, C., Wong, J.T., Casas, R., Lu, P., Alessi, C., Josephson, K. (2007). Predicting caregiver burden from daily functional abilities of patients with mild dementia. *Journal of the American Geriatrics Society,* 55(5), 1415-1420.

Redline, S., Yenokyan, G., Gottlieb, D.J., Shahar, E., O'Connor, G.T., Resnick, H.E., Diener-West, M., Sanders, M.H., Wolf, P.A., Geraghty, E.M., Ali, T., Lebowitz, M., Punjabi, N.M. (2010). Obstructive sleep apnea-hypopnea and incident stroke: The sleep heart health study. *American Journal of Respiratory and Critical Care Medicine,* 182(2), 269-277.

Richardson, C.R. (2010). Objective monitoring and automated coaching: A powerful combination in physical activity interventions*. Physical Therapy Reviews,* 15(3), 154-62.

Roberts, C. Mort, M. (2009). Reshaping what counts as care: Older people, work and new technologies. *ALTER, European Journal of Disability Research,* 3(2), 138-58.

Schneider, T. & Stanley, N. (2007). Impact of nocturia on sleep and energy. *European Urology Supplements,* 6(9), 585-593.

Sisson, S.B., Camhi, S.M., Gurch, T.S., Tudor-Locke, C., Johnson, W.D., Katzmarzyk, P.T. (2010). *American Journal of Preventive Medicine,* 38(6), 682-683.

Stone, E.F.W., Banerjee, T.W.D., Giger, J., Krampe, J., Rantz, M., Skubic, M. (2009). Testing an in-home gait assessment tool for older adults. 31st Annual Conference of the Institute of Electrical and Electronics Engineers, Engineering in Medicine and Biology Society, 6147-6150.

Trafton, A. (2006). Balance problems? Step into the iShoe: MIT grad student's invention could one day prevent falls. MIT News. http://web.mit.edu/newsoffice/2008/i-shoe-0716.html. Accessed April 4, 2012.

Tyrer, H.W., Aud, M.A., Alexander, G., Skubic, M., Rantz, M. (2007). Early Detection of Health Changes in Older Adults. Proceedings of the 29th IEEE Annual International Conference of the Engineering in Medicine and Biology Society, 4045-4048

Verbrugge, L.M., Jette, A.M. (1994). The disablement process. *Social Science and Medicine,* 38(1), 1-14.

Virone, G. (2009). Assessing everyday life behavioral rhythms for the older generation. *Pervasive and Mobile Computing,* 5(5), 606-622.

Wakabayashi, C., Donato, K.M. (2006). Does caregiving increase poverty among women in later life? Evidence from the Health and Retirement Survey. *Journal of Health and Social Behavior,* 47(3), 258-274.

Webb, E., Blane, D., McMunn, A., Netuveli, G. (2011). Proximal predictors of change in quality of life at older ages. *Journal of Epidemiology and Community Health*, 65(6), 542-547.

Zelinsky, A. (2009). Robot suit hybrid assistive limb. *Robotics & Automation Magazine, Institute for Electrical and Electronics Engineers,* 16(4), 98 and 102.

Zhang, K., Pi-Sunyer, F.X., Boozer, C.N. (2004). Improving energy expenditure estimation for physical activity. *Medicine & Science in Sports & Exercise,* 36(5), 883-889.

Zhang, K., Werner, P., Sun, M., Pi-Sunyer, F.X., Boozer, C.N. (2003). Measurement of human daily physical activity*. Obesity Research,* 11(1), 33-40.

CHAPTER 9: HEALTH INFORMATION TECHNOLOGIES AND THEIR INTERPLAY WITH OTHER AGING SERVICES TECHNOLOGIES

9.1. Introduction

The preceding chapters of this report describe various technologies to assist older adults and people with disabilities. These include implanted and wearable devices, sensors that are embedded in users' homes, approaches to the delivery of health-care services from remote locations, and technology-enhanced improvements of common assistive devices, such as canes and hearing aids. These aging services technologies (ASTs) seek to address a wide array of problems, including limited mobility, poor vision, and a variety of challenges associated with the management of common chronic conditions of aging.

A key feature of many of the ASTs that are explored in this report is their ability to generate, collect, and transmit health information that is not usually collected as part of routine medical care. There are many examples of this type of information, including gait instability and sleep quality collected from home-based sensors, adherence to prescription drug regimens collected from medication management technologies, and diabetes self-management activities collected through remote patient monitoring (RPM) technologies. The data collection and management functions of ASTs have the potential to create synergies for patients, providers, and caregivers when interfaced with health information technologies (health IT) (Blumenthal and Glaser, 2007). Common examples of health IT include electronic health records (EHRs), personal health records (PHRs), and electronic prescribing.

If effectively integrated with one another, ASTs and health IT can work in conjunction as especially rich sources of health information that could enhance the quality of clinical care and decision-making. Health IT systems with which ASTs could interface range from those that store and report information, such as laboratory results, to those that share information about patients across institutional and geographic boundaries, to more complex systems that provide clinicians with real-time alerts and provide clinical decision support (CDS) based on all available patient information. Recent initiatives and policies encouraging the adoption of health IT, coupled with a growing awareness of the importance of both health IT and ASTs on the part of providers, patients, disability services, family and community stakeholders suggest that the next few years may bring new opportunities to leverage these resources for the collective benefit of all stakeholders. However, although meaningful efforts are underway to facilitate the interplay between health IT and ASTs, a number of significant challenges remain to be addressed before this goal is met.

9.2. The Interplay Between Aging Services Technologies and Health Information Technology

If fully and appropriately integrated, ASTs and health IT can provide patients, clinicians, and caregivers with enhanced information that can not only improve patient self-management and provider care management and decision-making, but also reduce burden on informal caregivers. For example, integration of sleep quality and medication data into patients' personal health records (PHRs) facilitates access to personalized information about specific health conditions and self-management challenges. This type of readily available information empowers patients to become effective partners in managing their health and health care. Moreover, integration of data from patients' ASTs into EHRs can supplement the information captured during office visits with additional, targeted longitudinal data, resulting in a more comprehensive picture of patient health. An AST-enhanced EHR of this type would provide clinicians with important, timely information that would otherwise not be available, and that could be used in making complex care decisions, such as adjusting medication dose in response to monitoring data. Additionally, the integration of health IT and ASTs can help ensure that providers, patients, and caregivers alike have access to the most current data to help them discuss and develop the most appropriate treatment protocols. Medication management and remote patient monitoring offer examples of how ASTs may interface with health IT to create synergies that cannot be realized when either technology is used alone.

Chapter 1 of this report discusses care issues and ASTs that are relevant to the risk of falls, a serious and costly outcome that becomes more likely as individuals age. Technology-enhanced strategies to reduce the risk of falls have been developed for both acute and long-term care (LTC) settings, as well as for home use, and many of these technologies can interface with health IT. For example, CDS systems can alert clinicians to factors that may increase the risk of a fall, including side effects or interactions among medications. Health IT can also guide physicians in implementing post-fall interventions that facilitate rehabilitation, thereby reducing the risk of subsequent falls. There are also many products on the market that are designed for home use, and these can also interact with health IT in ways that inform patient care. For example, many technology-enhanced fall prevention strategies involve tracking the user's activities, including the number of steps taken, walking velocity, stride, balance, and other fall-related factors. These systems often have the capacity to transmit data to health-care professionals, to store data in a PHR, or to integrate data into an EHR in a manner that helps identify changes in an individual's fall risk and thus provide alerts when intervention is needed. In addition to improving health outcomes by reducing the prevalence of falls and associated health problems, AST and PHR/EHR integration can provide patients, providers, and caregivers with greater peace of mind in the knowledge that changes in fall risk can be detected and acted upon.

The role of ASTs in chronic disease management is explored in Chapter 2 of this report. A key issue in this chapter is clinicians' need for longitudinal measurements on key parameters, not just “snapshot” data collected during office visits. A number of RPM technologies that are designed for home use have the potential to achieve this goal and enhance the impact of health IT by supplementing EHR data with additional, disease-specific information collected between office visits. For example, a diabetic patient's glucose measurements can be consistently tracked by RPM technologies that transmit this information to a primary-care provider who can identify any clinically meaningful changes in glucose that warrant action. In addition to helping clinicians identify actionable health events that occur between patient office visits, the serial data collected by these systems can help EHRs and PHRs become dynamic, rather than episodic sources of health information that allow providers to consider the totality of all available information when making decisions.

Chapter 3 examines the importance of medication management among older adults and people with disabilities because these populations often may take multiple medications that are prescribed by a variety of providers and filled by more than one pharmacy. Differing administration schedules and dosing are additional factors that contribute to medication errors and adverse drug events among these populations. Specific EHR functions, such as electronic prescribing and CDS-assisted prescriptions, are examples of health IT functions that can facilitate medication management by reducing these challenges. Integrating electronic medication administration records and medication adherence data into EHRs provide additional examples of how medication-focused technologies can work with health IT to enhance the availability of information to help clinicians improve patient care. ASTs such as medication reminders, dispensers, and monitors can enhance the utility of health IT by providing medication compliance information and adherence processes.

For example, home-based medication management systems that can transmit data to the user's health-care provider can supplement EHR data in a manner that gives the clinician detailed information on numerous parameters related to patients' medication adherence, information that is not otherwise available to the clinician. These systems can alert the provider if a patient's medication is not taken, filled, or refilled as prescribed. Availability of this information could help with clinical decision-making in situations where unfavorable signs and symptoms could be caused by an allergic reaction to a prescribed medication, a drug interaction, or non-compliance with appropriately prescribed medication.

The relationship of ASTs in detecting and treating depression is the focus of Chapter 6. Telemental health strategies, such as those employed by the Veterans Administration, offer a particularly good example of the interface of ASTs and health IT in this area. These technologies allow patients to access their PHRs, transmit vital signs, and interact with mental-health professionals across long distances. Data generated through telemental health encounters then become part of the patient's EHR. When combined with other EHR data, including prescription medications the patient may be taking for other health issues, mental-health information can be viewed and interpreted in the context of the patient's full clinical profile, thereby providing clinicians with a more detailed and complete picture of the patient and most appropriate interventions.

Chapter 8 of this report explores ASTs in the context of functional decline. Technologies targeting this broad care issue often involve monitoring physical function (e.g., activities of daily living) through wearable devices or systems of sensors that are embedded in the environment. Depending on the complexity, these technologies can generate multiple data streams that track diverse measurements ranging from ambulation to sleep quality. All of these data can interface with health IT in ways that provide clinicians with a more complete and dynamic patient profile. They can also provide timely insight into changes in functional status that may signal changes in underlying health status, emerging or worsening impairment, or the need for modifications in the patient's care plan. For example, sleep disturbance monitoring systems, such as actigraphy, a wrist-based sleep monitor that uses wrist motions to track sleep disturbance; and ballistocardiography, a bed-sensor-based system that measures patients' sleep movement to detect disturbances, stream data to clinicians on parameters that can assist in the mitigation of sleep apnea and other sleep disturbance conditions that might otherwise go undetected.

In addition to providing access to clinically relevant, longitudinal information on physical function, these technologies allow clinicians and caregivers to respond quickly to changing functional status and care needs, and can be particularly valuable at times when older adults and people with disabilities are transitioning across care settings (e.g., to better inform transfer and discharge planning). In addition, including functional status information in a PHR that is accessible to family and/or professional caregivers allows them to coordinate and deliver supportive services that protect patients' independence. This comprehensive data profile can improve caregivers' ability to detect changes in health status and chronic conditions early on and thereby facilitates accurate diagnoses and better care. Finally, integrating activity monitoring data with electronic prescribing can provide insight into potential side effects of newly prescribed drugs and provide clinicians with an opportunity to modify drug regimens using information that would otherwise be unavailable.

The effective integration of ASTs and health IT has the potential to facilitate care delivery across multiple provider settings, generate significant improvements in quality and the patient experience, and help contain health-care costs. However, while many existing systems and devices allow such integration, challenges remain with respect to their widespread use in order to realize these benefits. The following section provides an overview of these challenges, which cut across multiple care settings and forms of technology, and highlights some of the progress to date in surmounting them.

9.3. Barriers to Integrating ASTs with Health IT

Although there are many examples of how ASTs and health IT can work together to dramatically enhance care and the experiences of patients, providers, and caregivers, there are significant barriers to this integration, chief among which are issues associated with interoperability, as well as privacy and security.

Interoperability

The synergies that can be realized through the interface of ASTs and health IT are predicated on interoperability, which can be defined simply as the ability to exchange data or information (Mead, 2006). Without it, the benefits offered by these technologies can only be realized independently (Martin, 2007). In the context of medication management, for example, available technologies and health IT in settings that provide care to older adults and people with disabilities often lack interoperability or even connectivity. Furthermore, the individual components of these systems such as bar-code administration, decision support applications, and pharmacy database systems may operate independently in a single care setting due to lack of interoperability (National Academy of Sciences, 2007). Basic issues such as the absence of data-entry standards, differing data formats, and dissimilar interfaces can pose challenges for interoperability and information exchange. These technical considerations often inhibit progress toward effective interfacing of ASTs and health IT, even among stakeholders who recognize the value of this integration (Bates et al., 2001).

A number of strategies are being pursued to address interoperability issues, many of which focus on common approaches to structuring and formatting health information so that data can be more seamlessly integrated and easily exchanged. For example, the data exchanged between ASTs and health IT must contain standard medical terminology so that the information is unambiguous. This "semantic interoperability" requirement permits data exchange and processing across platforms by relying on a shared understanding of common information. For example, if sensor-based data are to interface with an EHR in a way that can alert providers or caregivers about the possibility of a fall, the terminology and data used to describe ambulation, posture, gait, weight, and other factors need to be defined and interpreted by both technologies in the same manner.

Another important component of information exchange is "syntactic interoperability," which refers to the ability of data to be exchanged while allowing messages sent from one system to be processed by another in a way that identifies where relevant data are located (e.g., with a message containing a header, a glucose measurement, and the date and time of the measurement). This process occurs through application of data standards for system messaging. Health Level Seven (HL7) is one of the most widely used standards for clinical information system messaging (Mead, 2006). Each HL7 message has a unique structure composed of segments for each field in the patient record. Thus, one segment will have demographic information, while another may have information on medication history. If an AST sends an HL7 message to an EHR that can process these messages, then the EHR will be able to identify, locate, and store information regarding the individual’s medical history, current clinical condition, allergies, or contraindications without compromising any data in the exchange. If, on the other hand, the EHR cannot process HL7 messages, it may fail to integrate some or all of the information from the AST.

As older versions of HL7 standards (i.e., version 2.x) cannot handle full semantic or syntactic interoperability (Mead, 2006), the evolution of the HL7 standard to Version 3.0 is one approach to addressing the interoperability challenges that characterize Version 2.x. A particularly important feature of Version 3.0 is a Reference Information Model (RIM) that provides unambiguous definitions of the semantics in most clinical messages (Mead, 2006). This improvement facilitates semantic and syntactic interoperability, fundamental features of information exchange that were cost-prohibitive in Version 2.x. Additional efforts are underway to address other barriers to interoperability, some of which focus on care settings of central interest to older adults and people with disabilities. For example, HL7 defined the essential functions of EHR systems to be used in LTC settings, where ASTs may be of particularly high value to patients, providers, and their families (Health Level Seven, 2010). These functions include functional assessment questionnaires and three-way e-prescribing, which may both be important in the future, and other functions that can be considered optional. Criteria for determining conformance with these new profiles were also established to serve as a reference for parties wishing to develop or purchase EHR systems that are interoperable with ASTs in the LTC setting.

Integration of telehealth data into EHRs provides clinicians and care providers with continuous information about patients' health status between office visits. This has now become possible due to a recent HL7 standard called the Personal Health Monitoring Report (PHMR), which is based on the HL7 Clinical Document Architecture (CDA) that specifies the structure and semantics of clinical documents for the purpose of information exchange (Health Level Seven, 2011). It applies a detailed format to transform diverse types of data into standardized PHMR documents. The resulting documents are evaluated to determine conformance with this format, thereby enhancing semantic interoperability (Health Level Seven, 2011).

These same standards can offer opportunities for interfacing AST and health IT that extend beyond telehealth. Other recently developed interoperability standards relevant to LTC and post-acute care settings include:

1. The HL7 CDA for the Continuity of Care Document (CCD) Standard (Health Level Seven, 2010), which facilitates electronic exchange of patient summaries between settings primarily during transfers (e.g., from a LTC facility to a hospital);
2. The National Council for Prescription Drug Programs (NCPDP) Script 10.6 Standard, which allows LTC facilities to electronically enter and deliver prescriptions and physician orders to a pharmacy (National Council for Prescription Drug Programs, 2010); and
3. The CDA Framework for Questionnaire Assessment (Health Level Seven, 2011), which allows standardized capture and exchange of functional assessments, including federally mandated assessments like MDS and OASIS that are relevant in LTC settings.

Despite this progress, however, more interoperability standards are needed for sensor-based and wearable activity data, functional assessments and information about ADLs that can be inferred from sensor data, sleep quality assessments, computer-based cognitive assessments, and medication administration and adherence records to more fully integrate ASTs with other health IT systems and maximize their potential. Further, these standards will not only facilitate transmission of device data to health-care providers, but will also ensure that data can be shared among providers, patients, and caregivers to grant all parties equal access to critical health information.

Privacy and Security

Although ASTs have the ability to improve the daily lives of older adults and those with disabilities, improve care coordination, reduce provider and caregiver burden, and reduce health-care costs, concerns remain regarding the privacy and security of health data collected by these technologies and exchanged across platforms. Patients have an expectation that their health information will remain private, accessible only to individuals directly involved in their care and it will not be made public or shared in other ways. They also expect that this information will be secure, meaning that organizations maintaining patient data have safeguards in place to ensure that private health information is not stolen, lost, or inappropriately disclosed to unauthorized parties. Specific examples of privacy and security concerns include security breaches by hackers in search of personal information, and unauthorized disclosure of sensitive information such as HIV status.

Data-sharing among information systems, providers, and care settings, including that which occurs at the interface of ASTs and health IT must address the need for both privacy and security. These concerns may be particularly relevant to older adults and people with disabilities who are more likely to obtain services from a large number of providers relying on a range of data sources.

The Health Insurance Portability and Accountability Act (HIPAA) was enacted to ensure the privacy and security of individuals' identifiable health information and, in part, to improve the efficiency and effectiveness of the health-care system through the adoption of national standards for electronic health care transactions. The HIPAA Privacy and Security Rules require privacy and security protections for individuals' health information--paper, electronic, and oral communications--collected or transmitted by "covered entities." HIPAA applies to any provider that bills electronically, including a diverse array of entities such as hospitals, private practices, nursing homes, and home health agencies. These covered entities are some of the primary agents capturing patients' health information, and they are also the entities most likely to see the benefits of the enhanced interplay between ASTs and health IT. For example, a home health agency may deploy telehealth devices in patients' homes to capture vital signs and perform remote monitoring to assist with the management of chronic conditions. These data may then be imported into EHRs maintained by primary-care physicians and potentially shared with specialists. However, the use of these devices by covered entities may raise potential privacy and security concerns and thus pose certain challenges under HIPAA rules because they may not be designed with appropriate security features to guard against unauthorized access to patient information. For example, electronic blood pressure cuffs that store and transmit readings often lack features such as password protection. Moreover, if the data transmissions are facilitated and/or stored by a third party that is not a covered entity, such as a technology vendor, patients and physicians may require reassurance that the company adequately protects and secures this information.

Even in settings where ASTs and health IT have been effectively integrated, there are concerns about PHI security with respect to access control. Health IT systems are set up as networks that store and manage patient data and users with appropriate privileges can access this information for a variety of functions related to patient care and are often able to share this information across organizational and provider boundaries (Gallaher et al., 2002). Although these exchanges help make health information available where it is needed, they can also pose challenges in terms of determining who needs access to what PHI data elements in which provider settings. These questions can be daunting for a number of reasons, including the large number of providers from whom older adults and people with disabilities receive care; the frequent use of emergent care among these patient populations; changes in patients' health status that might require modifications in access to their PHI on the part of their providers; as well as changes in providers and care settings. For instance, while the management of congestive heart failure may be the responsibility of a hospitalist during an acute-health episode, this responsibility may shift to a home-health agency after discharge and ultimately back to a primary-care physician after recovery. These factors can lead to inconsistent application of access protocols across providers and settings that may exacerbate concerns about unauthorized users' access to identifiable data--concerns that will only increase as information exchange becomes more widespread (Ferreira et al., 2006).

Recognizing that privacy and security issues pose significant challenges to information exchange and the full realization of its benefits, the Agency for Healthcare Quality and Research (AHRQ) and the Office of the National Coordinator for Health Information Technology (ONC) are leading a number of initiatives to better understand stakeholders' progress in planning and implementing health information exchange and the policies and infrastructure to support it. For example, ONC's State Health Information Exchange Program aims to assist states in developing comprehensive infrastructure for health information exchange (HIE) that allow health data collected at doctors' offices and other locations to be transferred seamlessly among various medical locations and technologies (Williams et al., 2012). Among the program's requirements is that states submit and implement robust privacy and security plans, utilizing encryption, controlled access, and other security measures to ensure that patients' health information is protected (Office of the National Coordinator, 2012). These plans also call for standardized approaches to user authorization and authentication, audits of patient record access and modification, identification of patients, and data security (Dimitropoulos, 2007b).

These strategies can also help address many of the privacy and security concerns that relate to the interface of ASTs and larger health IT systems. However, they are likely to be less useful for consumer-focused technologies such as those used in the home that have the capacity to transmit information to an EHR or PHR, and those that use internet and mobile technologies. For example, mobile devices can be tracked electronically and may lead to unintended exposure of the user's location, thereby compromising privacy. Thus, to ensure integrity and confidentiality, direct downloading of patient data to a personal digital assistant (PDA) owned by a health-care professional must be constrained by location or ownership information (Zheng et al., 2007). To address these issues, a growing body of research is focusing on developing mechanisms to address privacy and security concerns related to internet and mobile technology-based health-care applications (Zheng et al., 2007). For instance, efforts are underway to develop privacy trust negotiation protocols for mobile health-care systems that promote trust between mobile devices and back-end health information systems in compliance with predefined access control and disclosure policies (Dong and Dulay, 2006).

References

Alwan, M., Felder, R. (2008). *ElderCare Technology for Clinical Practitioners*. New York City: Humana Press.

Bates, D.W., Cohen, M., Leape, L.L., Overhage, M., Shabot, M.M., Sheridan, T. (2001). Reducing the frequency of errors in medicine using information technology. *Journal of the American Medical Informatics Association*, 8(4), 299-308.

Choi, Y.B., Capitan, K.E., Krause, J.S., and Streeper, M.M. (2006). Challenges Associated with Privacy in Healthcare Industry: Implementation of HIPAA and Security Rules, *Journal of Medical Systems*, 30(1), 57-64.

Dimitropoulos, L.L. (2007a). Privacy and security solutions for interoperable health information exchange: Final implementation plans. Rockville, M.D.: Agency for Healthcare Research and Quality, and the Office of the National Coordinator for Health Information Technology. http://healthit.ahrq.gov/images/jul07fip/fip.htm. Accessed April 4, 2012.

Dimitropoulos, L.L. (2007b). Privacy and security solutions for interoperable health information exchange: Nationwide summary. Rockville, M.D.: Agency for Healthcare Research and Quality, and Office of the National Coordinator for Health Information Technology. http://healthit.ahrq.gov/images/jul07nationwidesummary/nationwide.htm. Accessed April 4, 2012.

Dong, C., Dulay, N. (2006). Privacy preserving trust negotiation for pervasive healthcare. Proceedings of the IEEE Pervasive Health Conference and Workshops, 1-9.

Ferreira, A., Correia, R., Antunes, L., Palhares, E., Farinha, P., Costa-Pereira, A. (2006). How to break access control in a controlled manner. Institute of Electrical and Electronics Engineers Symposium on Computer-Based Medical Systems, 847-854.

Gallaher, M.P., O'Connor, A.C., Kroop, B. (2002). The economic impact of role-based access control. Gaithersburg, M.D.: U.S. Department of Commerce. http://www.nist.gov/director/planning/upload/report02-1.pdf. Accessed April 4, 2012.

Health Level Seven (2010). Continuity of care document. http://wiki.hl7.org/index.php?title=Product_CCD. Accessed April 4, 2012.

Health Level Seven (2011). Product CDA R2 IG. http://wiki.hl7.org/index.php?title=Product_CDA_R2_IG#Product_Name_-_CDA_R2_IG_QA_.28Questionnaire_Assessments.29. Accessed April 4, 2012.

Lovis, C., Spahni, S., Cassoni, N., and Geissbuhler, A. (2006). Comprehensive management of the access to electronic patient record: Towards trans-institutional networks. *International Journal of Medical Informatics*, 76(5-6), 466-470.

National Commission for Quality Long-Term Care. (2007). Essential but not sufficient: Information technology in long-term care as an enabler of consumer independence and quality improvement. http://www.ncqltc.org/pdf/BearingPoint_Report_for_NCQLTC.pdf. Accessed April 4, 2012.

Mead, C. (2006). Data interchange standards in health IT-- Computable semantic interoperability: Now possible but still difficult, do we really need a better mousetrap? *Journal of Healthcare Information Management*, 20(1), 71-78.

National Academy of Sciences (2007). Preventing medication errors: Quality chasm series. http://www.nap.edu/catalog/11623.html. Accessed April 4, 2012.

National Council for Prescription Drug Programs (2010). SCRIPT 10.6, Eprescribing fact sheet. http://www.ncpdp.org/pdf/Eprescribing_fact_sheet.pdf. Accessed April 4, 2012.

Office of the National Coordinator for Health Information Technology (2012). State health information exchange cooperative agreement program. Washington, D.C.: U.S. Department of Health and Human Services. http://healthit.hhs.gov/portal/server.pt/community/healthit_hhs_gov__state_health_information_exchange_program/1488. Accessed April 4, 2012.

Subramanian, S.H. (2007). Computerized physician order entry with clinical decision support in long-term care facilities: Costs and benefits to stakeholders. *Journal of the American Gerontological Society*, 55(9), 1451-1457.

Williams, C., Mostashari, F., Mertz, K., Hogin, E., and Atwal, P. (2012). From the Office of the National Coordinator: The strategy for advancing the exchange of health information. Health Affairs 31:3527-536.

Win, K.T., Susilo, W., Mu, Y. (2006). Personal health record systems and their privacy protection. *Journal of Medical Systems*, 30(4), 309-315.

Zheng, Y., Chen, Y., Hung, P.C.K. (2007). Privacy access control model with location constraints for XML services. International Conference on Data Engineering Workshop, 371-378.

CHAPTER 10: BARRIERS AND POTENTIAL STRATEGIES TO PROMOTE DEVELOPMENT, ADOPTION, AND USE OF AGING SERVICES TECHNOLOGIES

10.1. Overview

In fulfilling the requirements of the Aging Services Technology (AST) Study mandated in Section 13113(c) of the American Recovery and Reinvestment Act (ARRA) of 2009, the preceding chapters present information on available and emerging technologies for care issues that affect a great number of older Americans, people with disabilities, their caregivers, and health-care providers. The chapters also examine evidence on the effectiveness of these technologies in addressing these care issues and explore other countries' experiences with developing or supporting similar or new aging services technologies (ASTs). Given the interplay of many ASTs with EHRs and other forms of health IT, a separate chapter highlights how the effective integration of these technologies can improve their capabilities and functionalities, while increasing their benefits as well (Chapter 9).

Another requirement of the AST Study was to identify and examine barriers to the development, adoption, and use of ASTs by different stakeholders, as well as potential strategies for addressing them. While the original plan was to include discussion of these barriers in each care issue chapter, because many of them are common across care issues, they are presented together here in a freestanding chapter.

Not surprisingly, financial barriers to AST development are prominent and appear consistently across the care issues reviewed in this report, as well as in the broader literature on barriers to technology development. Due to limitations in governmental and non-governmental resources, strategies calling for expanded government coverage of ASTs are unlikely to be feasible in the absence of compelling evidence as to the savings that could accrue as a result of their use. However, as stated above, consideration of such strategies and the likelihood of their adoption are beyond the scope of this study. Accordingly, this chapter focuses on strategies for addressing barriers to AST development, adoption, and use that can be largely implemented with existing resources and infrastructures.

Some of the AST barriers explored in this chapter apply to older adults and individuals with disabilities who use these technologies, while others apply to caregivers and providers. Following a discussion of these barriers and how they relate to various stakeholders, the chapter presents potential strategies for addressing them, a discussion of barriers that are especially relevant to payers, and a discussion of barriers to AST development.

10.2. Barriers to Adoption and Use among Consumers, Caregivers, and Providers

Although previous chapters in this report summarize the research supporting the health benefits and cost savings of a number of ASTs, in practice, receipt of these benefits is predicated on the assumption that stakeholders first adopt ASTs and then sustain their use for a sufficient period of time to realize their benefits. However, a number of barriers inhibit adoption and use of ASTs, with these barriers often applying to multiple stakeholder groups.

Lack of Awareness and Evidence of Effectiveness

Research suggests that consumers and caregivers lack knowledge of existing ASTs, the value and utility of these technologies, as well as how to acquire and use them (Brownsell, 2004). Although lack of awareness is due in part to the novelty of some of these technologies, a more important explanation is the dearth of resources providing information about them, what they do, evidence of their benefits, where to purchase them, and how to use them.

Lack of AST awareness is present among not only older adults and informal caregivers, but also among paid caregivers and health-care professionals despite their role as trusted referral channels and influential change agents (LeadingAge CAST, 2008). One reason that health-care professionals are unaware of ASTs is that the professional, peer-reviewed literature to which they often refer for information and guidance does not contain a great deal of published research on ASTs or their interplay with health IT. Indeed, because professional societies often base continuing education and practice recommendations on accumulated evidence from peer-reviewed sources, it is not surprising that health-care professionals have had limited exposure to AST-related information. This gap in the scientific literature creates challenges for AST adoption among providers because many of these technologies have not been adequately evaluated in the field, and therefore often lack recognition from professional organizations (Wasson et al., 2008). Further, professionals may be reluctant to recommend AST use in the home for their patients because of the perceived and real lack of scientific evidence supporting their effectiveness.

In a health-care environment in which decision-making is increasingly evidence-based, the lack of published, quantitative information on the effectiveness of ASTs can dramatically inhibit adoption among providers and patients alike. Another consideration relevant to awareness of ASTs among providers is the fact that most physicians are trained in hospitals, but most consumer-focused ASTs are used in long-term and post-acute care settings, as well as in the home. As a result, physicians may not have adequate exposure to the breadth of technology-enhanced supports that are available to older or disabled patients outside of acute-care settings. Other professionals (e.g., hospital discharge planners) with a role in influencing receipt of post-acute services are also based in acute-care settings and may be similarly disadvantaged with respect to knowledge of ASTs.

Potential Strategies to Increase Awareness and Improve Evidence of Effectiveness

Strategies to increase awareness of ASTs include creative approaches to disseminating information from published peer-reviewed research about the efficacy and cost-effectiveness of many of these technologies. Research results could be efficiently disseminated through existing infrastructures and the resources of diverse professional, national, and community organizations that are relevant to AST stakeholders. For example, as part of their scientific meetings and scholarly publications, physician member organizations could be encouraged to develop continuing medical education and other professional activities that focus on increasing members' awareness of ASTs and the interplay between ASTs and health IT.

Another potential agent for dissemination is the Home Health Quality Improvement (HHQI) National Campaign. This is a joint project of CMS and the Home Health Quality Improvement Organization Support Center (HHQIOSC) to connect the home health community and Quality Improvement Organizations (QIOs), and to serve as a resource for improving patient care quality. To this end, HHQI could provide a platform for disseminating information about ASTs, including incorporating a discussion of ASTs into its best practice intervention packages (BPIPs), monitoring their uptake, and reporting the findings to assist with rectifying the general lack of awareness among consumers and caregivers. Further, the CMS-funded National Coordinating Center for Integrating Care for Populations and Communities is currently working to expand the diversity of HHQI users beyond home health to all health-care settings, making it a potentially powerful vehicle for increasing awareness among a broader health-care audience as well.

These organizations could also engage in other outreach activities to keep members informed about the value of ASTs; to facilitate understanding of how access to these technologies can be helpful to them, their patients, and patients' families; and to inform members about ongoing developments in the field. Further, the scholarly journals that are produced and edited by these organizations could promote research on ASTs' effectiveness by dedicating sections or an entire issue to AST research and by encouraging submission of letters and research notes focusing on the interface between ASTs and patient care. These approaches will not only help address barriers associated with awareness among health-care professionals, but they will also target the dearth of published research on the effectiveness of these technologies.

Private non-profit organizations focusing on service provision for older adults and people with disabilities could also play a pivotal role in increasing awareness of ASTs among consumers. National organizations represent thousands of social service agencies across the country, many of which provide diverse services to older adults and their families. These organizations could be encouraged to educate communities on the value of ASTs and promote their use among their constituencies. Local Area Agencies on Aging (AAAs), national family caregiver support programs, as well as aging and disability resource centers offer additional examples of national networks of aging-focused organizations with infrastructures that could be harnessed to increase awareness of ASTs among older adults and their families across the country. These efforts could be supplemented by continued efforts by federal agencies, as well as support from the AAAs in collaboration with other organizations that have expertise in ASTs, or in offering information on technology-enabled care and support services.

Stigma

The stigma associated with some ASTs on the part of older adults and individuals with disabilities has a direct impact on adoption and sustained use of these technologies. For example, one study of personal emergency response systems (PERS) showed that 80 percent of older adults with these systems who had fallen did not use their alarms, and that chief among the reasons for reported non-use were concerns about independence and perceptions on the part of the users that they did not need help (Fleming and Brayne, 2008). Stigma is a particularly difficult challenge with assistive devices that are visible to others (e.g., hearing aids and wheeled mobility equipment [WME]) because these technologies can unfavorably influence users' feelings about themselves, and also raise concerns among users about others' perceptions of them. For instance, older adults may be concerned that using a fall detection technology signals vulnerability or frailty to others, creating a sense of loss of independence. Similarly, WME users may have concerns about the perceived negative connotations associated with the use of these devices, and thus may be reluctant to use these devices despite the potential benefits that can be realized by their use (LaPlante and Kaye, 2010). Feelings of stigma can not only influence users' willingness to use ASTs, but also adversely impact how the technologies are used (e.g., episodic, rather than continued use) among those who do adopt ASTs and diminish the assistance and benefits they provide (Sirey, Bruce, and Alexopoulos, 2005).

Potential Strategies to Address Stigma

One approach to dealing with AST-associated stigma involves achieving a better understanding of its specific underlying factors among older adults and people with disabilities, and using this understanding to provide families with new strategies and tools that will help them to encourage adoption and continued use of these technologies. For example, children of older adults who are at high risk of falling may benefit from innovative approaches to communicating the utility, value, and social acceptance of a home monitoring or PERS system. It is not surprising that addressing the psychological and social factors associated with AST use has been proposed as a key strategy to ensure both the adoption of and compliance with these technologies (Kim, Paper, and Weiner, 2002). Similarly, improved understanding of the components of AST-associated stigma could help technology developers address these concerns in the design stage by making ASTs less conspicuous and more aesthetically appealing. These strategies could be augmented by additional approaches such as public education campaigns that could be implemented at the community, state, or national level (Conner, 2008). These campaigns could target consumers, caregivers, as well as providers in an effort to encourage social acceptance of ASTs, and to promote them as an extension of routine self-care. Additionally, such educational and outreach activities could be implemented by social service agencies, AAAs, and other established entities that are closely tied to local provision of aging services.

Privacy and Security

Issues related to privacy and security act as barriers to AST adoption for all stakeholders. Some of these issues were discussed in Chapter 9, which dealt with the interplay of ASTs and health IT. Similar privacy and security concerns exist for ASTs alone and can generally be divided into two categories: those related to protocols dictating the release of patient-level information from providers to other parties, and concerns about how information flows among providers and across care settings (National Research Council, 1997). Organizational policies regarding what patient-level information can be shared, with whom, when, and under what circumstances are often unclear and not communicated adequately to patients. As a result of these ambiguities, patients and family members may develop concerns about how electronic health information is maintained within health-care organizations (CAPSIL, 2007). In addition to intra-organizational data-handling ambiguities, patients and families may be concerned about issues related to the extent to which health information is shared across providers and provider settings. This is particularly relevant to older adults and people with disabilities because these groups often have complex medical profiles that involve receipt of care from multiple specialists in different facilities or different geographic locations.

The Health Insurance Portability and Accountability Act (HIPAA) applies to ASTs and other systems that collect, store, or transmit protected health information (PHI). Although this law was designed in part to protect privacy and PHI, it can also act as a barrier to AST use. The HIPAA Privacy Rule sets boundaries on the use and release of health records and generally limits release of information to the minimum that is needed for the purpose of disclosure (U.S. Department of Health and Human Services, 2006). As a result of these efforts to protect and empower patients (as well as concerns about civil and criminal penalties for violating patients' privacy), many providers have responded by imposing strict regulations on the sharing of health information outside of their institutions (Mandl, Szolovits, and Kohana, 2001). In some cases, concerns about these penalties may drive providers to take more extreme measures that may restrict patients’ access to their own health information and impede the sharing of important information among care providers, particularly related to transitions of care. Such restrictions on the flow of health information across institutions can reduce the utility and impact of ASTs that rely on smooth information flow between and among providers.

Along with health information privacy concerns, personal privacy concerns have also been raised about the fundamental nature of some ASTs. For instance, wearable electronic tracking devices that are designed to address wandering behaviors are viewed by some as intrusive on individual freedoms, particularly when use of these technologies is initiated by someone other than the patient or when the user is unable to provide consent because of cognitive impairment (Abowd et al., 2002). Similarly, some home-monitoring systems and smart homes involve video cameras or other technologies that closely track and transmit information on patients' movements. Concerns have been raised about privacy and consent in these settings as well (Gentry, 2009). Although family members are often supportive about the use of these technologies because they reduce caregiver burden and increase users' safety, some research suggests that families nonetheless have privacy concerns about their use (Landau et al., 2010).

Potential Strategies to Address Privacy and Security

Examples of approaches to address privacy and security concerns associated with ASTs include development of transparent data-sharing policies, securing the patients' or legal representatives' consent when it can be reasonably obtained, providing patients with opportunities to opt-out of information sharing, and modifying certain types of data to protect privacy without compromising the functionality, utility, and benefits of ASTs. Development, implementation, and monitoring of policies, procedures, and safeguards can help ensure AST data are accessible only to authorized users, that patient information is adequately protected and that it is shared only with people who need to see it (Gentry, 2009).

In terms of some of the personal privacy concerns involving use of ASTs by cognitively impaired older adults, these could be dealt with in a manner that leverages applicable guardianship and legal representation laws, as well as current efforts to encourage documentation of advanced directives. That is, family-based discussions about care, including end-of-life preferences, could be expanded to include discussions of ASTs. With increased awareness of ASTs, conversations focusing on whether wearable devices or in-home monitoring would be acceptable to an older adult could become part of routine advanced care planning and documentation, thereby eliminating concerns that cognitively impaired individuals are being monitored against their wishes. Existing research has already summarized evidence about effective approaches to advanced care planning. These strategies could be applied to discussions about preferences regarding AST use in old age or in cases of severe injury or disability that render patients incapable of expressing their wishes (Agency for Healthcare Research and Quality, 2003).

Privacy concerns about systems such as those that have video cameras installed in bathrooms (where many falls occur) can also be addressed using software functions that obscure image details, but still allow the system to perform the fall detection algorithms and relay an alert signal without an accompanying image when a fall is detected. Many ASTs are designed to avoid transmission of identifiable images when relaying data. Then, to address some of the broader aforementioned concerns about data security, many use secure connections and data encryption, or only provide data to a patient's authorized health-care providers. Activity-monitoring technologies are one example of a class of technologies that provide these protections. Educating consumers and caregivers about these types of protections using the approaches outlined earlier in this chapter may also help increase awareness of strategies that address the range of privacy and security concerns that AST use may raise.

Usability

Usability is critical to encouraging widespread adoption of ASTs (Agency for Healthcare Research and Quality, 2008). It is also critical for sustained use, which is central to realizing the benefits of these technologies. These issues are particularly relevant for older adults who have limited familiarity with technology and for people with disabilities whose physical limitations may create challenges to routine technology use (e.g., when paralysis of the arms impedes use of a hand-operated computer keyboard, mouse, touch-pad or touch-screen). A key factor affecting usability relates to the user interface. Many consumer-focused ASTs require a basic understanding of computer applications, which many older adults do not have. Even among older adults with computer skills, the capacity can be lost over time in the presence of cognitive and/or functional decline. Further, AST functionality can be hidden in layered menus that may be difficult for older users to explore and master. Older adults may therefore be resistant to adopt or quick to abandon ASTs if they are not easy to use. Other features of the user interface can also act as barriers to adoption and sustained AST use. For example, the touch-screens and small buttons on some mobile phones require fine motor skills that could pose challenges to both older adults and people with disabilities who experience difficulties with upper extremity function or dexterity. Medication management technologies that have small screens and multiple buttons provide additional examples of devices that may present barriers to effective use.

Electric wheelchairs can require fine motor skills of the hand for routine operation. Older adults and people with disabilities who utilize these wheelchairs must have the cognitive and physical abilities to maneuver using the joystick, a skill set that is sometimes absent in these populations (Yu, Spenko, and Dubowsky, 2003). Further, walkers, scooters, and similar motorized mobility technologies are often hard to maneuver in small areas and can be challenging to transport from place to place without outside assistance.

Effective incorporation of ASTs into daily routines is another barrier to usability. Older adults and people with disabilities who have developed longstanding routines may find it difficult to adopt and regularly use ASTs, particularly if the technology is not perceived as fully compatible with their existing routines. Although the added value of an AST may be obvious to both consumers and their caregivers, skepticism and inertia can be powerful forces acting against modification of existing behavior patterns (Veldhoven, Vastenburg, and Keyson, 2008). Medication management technologies that do not take lifestyle patterns into account are an example of ASTs that users may not be able to easily incorporate into their daily routine. Some medication management technologies have dosing and scheduling protocols that do not provide the flexibility that many older adults need because of their active schedules (Agency for Healthcare Research and Quality, 2008).

Usability issues also apply to caregivers who, along with users, are often intimately involved in operating and maintaining ASTs, as well as monitoring the information they generate. Optimally, these technologies reduce rather than increase caregiver burden. However, while many ASTs are effective monitoring tools, they can also increase caregiver burden by producing copious amounts of information that needs to be reviewed, and by generating false positives on occasion (e.g., an alert that a fall occurred when it did not) that leads to unnecessary action and anxiety. Finally, even the most user-friendly AST will not provide benefit to the user if it is unreliable. For example, if a device aims to read street signs for a visually impaired user, it needs to read a variety of street signs with a high degree of accuracy. If the device is not reliable, not only does it fail to benefit the user, it may also introduce a hazard if it provides inaccurate information. For instance, a technology that cannot read certain types of street signs accurately may direct a visually impaired person in the wrong direction, resulting in disorientation and anxiety for both the user and family members.

Barriers associated with usability also apply to providers. One study found that human/machine interface flaws in a Computerized Physician Order Entry (CPOE) technology created 22 types of new medication errors largely because of a deficient interface with the provider. This study reported that the technology had numerous lines of similar-looking text, did not have a windows-based structure or intuitive graphical navigation, and that small font sizes created difficulties in reading drug names and dosing levels. It is therefore not surprising that usability issues create significant barriers to AST adoption on the part of providers (National Academies Press, 2007). In addition to technical usability issues, the “digital divide” that is characteristic of at least some LTC facilities, can present a significant barrier to AST adoption and implementation. Many care settings lack a sophisticated “computer culture,” have minimal computer equipment available and little use of it, and poor computer literacy among staff members. Therefore, to achieve the more widespread and effective use of sophisticated technology, these facilities must first surmount fundamental obstacles such as computer literacy and comfort.

Potential Strategies to Address Usability

User-related issues can be addressed most effectively in the design phase, when an AST is first being developed. The likelihood of favorable usability and acceptability ratings is generally higher when devices are developed with input from intended user groups. ASTs are unique in that both patients and caregivers purchase these technologies, and therefore devices must appeal to two sets of overlapping, but not identical user preferences. This context is important to understand because a device that improves patient health but is difficult for a caregiver to operate is less likely to be purchased and adopted than a device that meets the demands of both the patient and caregiver (Mahoney et al., 2007). "User-centered design strategies" take these factors into account and address them by engaging AST users during certain phases of the design process, whether they are patients, caregivers, or care providers. These strategies can involve convening focus groups during the development phase to ascertain users' specific needs; product testing of prototypes to determine how well users interact with and/or feel a device meets their needs (e.g., large displays, intuitive controls); and education and training for caregivers, patients, and providers when the device becomes available on the market for purchase.

For maximal adoption and sustained use, it has been proposed that ASTs should be aesthetically appealing to users, non-intrusive, discreet, and non-stigmatizing (Boissy et al., 2007). Examples of design efforts to address these criteria include: large buttons that are easy to press and highly visible; batteries that do not require frequent replacement; home-based systems and devices that are small in size, easy to navigate, do not create an 'institutional feel', and do not compromise users' sense of dignity and independence (e.g., small hearing aids that match the user's skin tone or are worn inside the ear canal). In spite of these design-related efforts to improve usability, perceived or actual burden on the user can result in non-compliance. In situations where compliance is anticipated to be a meaningful barrier to adoption or sustained use, ASTs that involve passive monitoring rather than active engagement on the part of the user can provide a solution (LeadingAge CAST, 2008).

Education and training that target all user groups are important means of addressing barriers to usability. Strategies that can help older adults and people with disabilities, as well as their families and professional caregivers become comfortable with ASTs as well as "low-level" computer software, include classes that are tailored specifically for each market segment, the provision of appropriate training materials (e.g., simplified manuals and step-by-step user guides), the establishment of community-based technology mentoring programs aimed at encouraging use of ASTs, and the distribution of demonstration videos (Gilly, Schau, and Wolfinbarger, 2003; National Alliance for Caregiving 2011). Many of these educational programs could take place in collaboration with existing community-based resources such as local senior centers, AAAs, aging and disability resource centers, national family caregiver support programs, and faith-based senior groups. They could also occur in collaboration with the types of online communities described in Chapter 6, which explored social-networking technologies to address depression.

Addressing issues associated with AST reliability is another approach to mitigating usability barriers. A device that does not function consistently and reliably will lead to distrust and discontinued use. Durability is a related concept that is especially important for ASTs that are worn or otherwise used actively and frequently by patients or caregivers. Extensive testing of technology prototypes under different operating conditions in both the lab and the field can help identify any reliability and durability issues and allow designers and developers to address these issues before bringing the technology to market. Ideally, field testing would recognize the diversity of residential settings in which older and people with disabilities live, and involve adequate testing in all of these settings to ensure equal reliability across these settings.

Provider Workflow and Interoperability

As discussed in earlier chapters and especially in Chapter 9 of this report, which dealt with the interface of ASTs and health IT, a number of provider-focused technologies (e.g., telehealth, telepharmacy) that are relevant to older adults and people with disabilities have the potential to be integrated with health IT. Consumer-focused technologies (e.g., remote patient-monitoring systems) also have this potential, although many of these can also operate as stand-alone systems. Despite this potential, there are challenges associated with integrating ASTs with health IT. These barriers often involve considerations related to disruptions in provider workflow and interoperability between ASTs and health IT.

In provider settings where ASTs are integrated with health IT or where ASTs are initially implemented, providers may perceive the technology to be impractical, rigid, or complex. They may also believe that new technologies disrupt workflow and add little value to patient care relative to the additional effort, cost, and perceived interruption (Balfour et al., 2009). In some cases, these perceptions are substantiated by the requirements that are imposed by certain technologies. For example, systems that are designed to reduce medication errors generate computerized alerts or warnings that induce clinicians to reconsider their actions in the course of routine patient care. These alerts can be regarded as "workflow blocks" if physicians have to work around the alert to access other screens or to continue in the course of care.

It has also been shown that clinicians tend to override alerts if they occur in large numbers (National Academies Press, 2007) and that repeated false alarms or a high volume of marginally medically consequential alerts can lead to “alert fatigue” on the part of users that reduces the overall value of the technologies themselves. Indeed, clinician bypasses or systematic adoption of workarounds can result in errors that can jeopardize patients (Vogelmeier, Halbesleben and Scott-Cawiezell, 2008). The workflow of non-physician staff can also be disrupted as a result of improper implementation of ASTs, thereby increasing staff time and labor costs. For example, the implementation of an EHR system without electronic medication administration and point-of-care documentation when medications are administered in a nursing home would force nurses to document administration on paper and then enter this information into the EHR at the nurses’ station, thereby introducing not only avoidable steps, but also the possibility of transcription errors. Beyond the disrupted workflow that results from system design, productivity often declines when a new system is implemented and staff members need to learn how to use it. Inadequate training and monitoring during this critical period can further contribute to difficulties in smooth implementation of new technology-enhanced patient care systems.

Interoperability presents another barrier to AST adoption. In settings where health IT is in place and functioning well, integration of new ASTs into existing systems may be inhibited by the interoperability issues outlined in Chapter 9. This may be particularly challenging for ASTs designed for use in the home. For example, consumer-focused remote monitoring systems that can track important clinical information such as blood pressure may not be easily incorporated into EHRs. Further, the relatively large number of AST products on the market creates practical challenges for integrating information into patient records due to lack of standardization of data elements and data formats.

Finally, acute, post-acute, and long-term environments often lack electronic data interoperability and interconnectivity. Data elements that are particularly relevant for older adults and people with disabilities (e.g., ADL-related functions) are not typically collected in routine EHRs that are maintained by acute-care facilities. These practical challenges pose significant impediments to the integration and use of AST data in a manner that can directly benefit older and people with disabilities who are frequent users of post-acute and long-term care (LTC). A system-level example of an interoperability consideration that is specific to the LTC setting involves e-prescribing systems. These systems were originally designed for two-way communication (physician to pharmacy) and not the three-way communication that is often needed in these settings (e.g., LTC facility to physician to pharmacy) (Spiro, 2008). Another example is the challenge of integrating medication adherence records, obtained from monitored medication dispensers, into primary care physicians' EHRs, which may be unable to capture and process this type of data.

Potential Strategies to Address Provider Workflow and Interoperability

It is critical that, prior to AST or health IT implementation, health-care providers and clinicians consider how technologies will be used and integrated into their organizational workflow. Thus, understanding and addressing workflow in different provider settings is crucial to the design and implementation of these technologies to help ensure that they are suitable for a given operational structure. Designs that accommodate these considerations and offer comprehensive and accessible patient profiles are likely to be favored over systems that do not (National Academies Press, 2007). Accordingly, solicitation of input from end-users during the development and implementation processes may be an easy and beneficial approach to addressing barriers associated with workflow. Further, systems that provide effective interfaces (e.g., clear presentation, inclusion of necessary details, and simple and easy-to-learn functionality) may amplify the benefits of ASTs, particularly when workflow is considered during development. Ensuring appropriate staff training before, during, and after implementation, along with a carefully monitored transition period, are also strategies that can maximize system uptake and sustained use and minimize adoption of workarounds or modifications in workflow that diminish use and the efficacy of the technology. Availability of effective post-implementation customer support can also supplement a closely monitored transition period and promote sustained use.

Incorporating ASTs with proven effectiveness into ongoing and newly initiated health-care delivery programs is another strategy that can promote AST adoption and use on the part of providers. There are a variety of innovative programs and approaches that cut across settings and that are structured to generate gains in both quality and efficiency. For instance, the Patient Protection and Affordable Care Act (ACA) offers opportunities for innovative health-care delivery approaches that can leverage increased adoption and use of ASTs to help increase the quality and efficiency of services provided in various health-care settings. Such programs (e.g., accountable care organizations (ACOs), bundled payment approaches, person-centered medical homes, home health services, and hospital readmission reduction programs) offer opportunities for increased quality and efficiency through incorporation of ASTs into their operational models. Under these programs, exchanging health information and coordinating care among providers, as well as with patients and their caregivers, are essential to gains in quality and efficiency of care while containing costs. The need for health information exchange, in turn, requires that technology vendors (of both ASTs and health IT) implement interoperability standards and work together on systems and data integration.

There have been several recently initiated efforts to overcome barriers to interoperability, and these are described further in Chapter 9. Examples of progress in this area include defining functional profiles with standard descriptions and a common understanding of the essential functions of EHRs to be used in LTC settings (Health Level Seven, 2012). The National Council for Prescription Drug Program (NCPDP) has created a standard called SCRIPT that facilitates transfer of prescription data among pharmacies, prescribers, intermediaries, and payers. SCRIPT has been endorsed by the federal government for use in electronic prescribing, and meets the needs of the LTC settings in which many older adults and people with disabilities receive services.

Liability

Some health-care professionals believe that ASTs could increase their liability exposure, thereby creating a barrier to adoption (LeadingAge CAST, 2008). There are numerous AST-related scenarios that providers believe could lead to litigation. For example, if an older adult with a remote-monitoring system falls and stops moving for a long period of time, the cessation of movement could be mistakenly interpreted by a staff person as a nap, rather than a fall. In this case, the fall could go undetected for a long period of time, ultimately potentially resulting in harm to the individual, additional service use such as a hospitalization, and/or legal costs that could have been avoided were it not for use of the technology (CNA, 2010). The perception that ASTs may increase liability risk is compounded by the widespread feeling that increased risk comes without accompanying benefits or protections (LeadingAge CAST, 2008). In addition to liability concerns related to the clinical application of ASTs, there are additional challenges related to litigation stemming from security breaches. For example, if a server is hacked resulting in the loss of private information such as Social Security numbers, diagnosis information, or credit card information, this could place providers at risk of litigation. These concerns are closely related to the discussion of privacy and security discussed earlier in this chapter.

Potential Strategies to Address Liability

Strategies to address providers' liability concerns include promoting a clear understanding both the strengths and limitations of the technologies, establishing internal procedures to mitigate true risks and clarifying providers' responsibilities in service agreements with patients and caregivers. These approaches can target both data security issues and potential physical harms that may result from using the technologies. Providers and other staff can also be engaged in ongoing education regarding data security, systems can be set up to require periodic password changes and data security certifications can be developed and mandated for appropriate staff. Another approach to mitigating liability concerns stemming from data security is for technology developers to include legal experts in the review of system security procedures and documentation (CNA, 2010). Providers can generate demand for heightened security by purchasing data systems that meet specific security thresholds. These include implementing firewalls, security certificates authentication, device-level authentication, and strong passwords, among others. In addition, service providers can institute protocols that respond to potentially high-risk scenarios. Using the example of a lack of movement from a remote-monitoring system, a staff member could call the individual's home to check in if the system does not generate a motion alert. If there is no answer, a staff member would be dispatched in a campus setting or emergency services would be called in a community setting. Thus, data generated by ASTs themselves could be harnessed in new ways to reduce liability exposure while simultaneously increasing safety.

10.3. Barriers to Adoption Associated with Payers

Again, while alternative financing strategies are beyond the scope of this study, it bears mention that, at present, neither public nor private payers have meaningful incentives to cover the costs of ASTs or the professional services they deliver. In many cases, lack of coverage is associated with the absence of compelling scientific evidence supporting the cost-effectiveness of these approaches under prevailing pay-for-service models. However, even in cases such as telehealth where there is evidence supporting the technology's benefits, incentives are not aligned in a manner that promotes broad coverage of ASTs by public or private payers. Similarly, RPM systems and the costs associated with ongoing monitoring are not covered by most insurance. There are, however, some Medicaid home and community-based (HCBS) waiver programs that provide coverage for PERS (in 44 states), telehealth (in 7 states), medication management services (in 16 states), and behavioral monitoring (in 1 state) (LeadingAge CAST, 2011a). Although these benefits are important, they do not reach the vast majority of older adults and people with disabilities who could potentially benefit from access to these technologies.

Potential Strategies to Address Barriers to Adoption Associated with Payers

Given the difficulties associated with extending reimbursement to ASTs and that financing is not a focus of this study, the following discussion focuses on strategies to address payer-related barriers without major changes or expansions in financing. These strategies generally involve efforts to better align incentives to encourage providers to appropriately and effectively adopt ASTs. A number of initiatives are currently underway that could help to achieve this goal, and others could be implemented by leveraging existing infrastructures and initiatives in new ways. One example of efforts to align incentives involves provisions under the ACA that reduce Medicare payments to hospitals with high readmission rates (Congressional Research Service, 2010). If ASTs or the interplay of ASTs with health IT were found to effectively reduce preventable readmissions, adoption and/or partnering with long-term and post-acute care providers who use such technologies effectively might become more attractive for hospitals. Thus, efforts to generate this evidence may result in adoption of ASTs with the goal of reducing readmissions.

A lack of compelling research on the efficacy and cost-effectiveness of novel care models that could be enhanced with ASTs is a barrier that cuts across the care issues outlined in this report. Without robust data supporting the role of ASTs or the interface of ASTs and health IT in improving care and health outcomes and reducing costs, payers will have limited incentive to encourage the adoption of these technologies. The ACA established the Center for Medicare and Medicaid Innovation to help identify promising innovative practices that deliver better care at lower cost. Substantial resources are now being made available to communities, health systems, and other organizations around the country to help achieve the Center's goals. It is also important to note that an increasing number of technologies and telehealth services are eligible for reimbursement if certain criteria are met. For new technologies that are not currently reimbursable, CMS has a formal process to evaluate technologies that show promise for the effective treatment or diagnosis of illness or injury to determine coverage.

The emergence of ACOs may offer another opportunity to align incentives in a manner that promotes AST adoption. These provider groups, consisting of hospitals, physician practices, and other health-care providers, partner to provide high-quality, coordinated care to patients (while affected patients are primarily Medicare beneficiaries, private payers are also partnering with ACOs to provide more efficient health care to their patients). Other participating organizations may include long-term care, home health, and other providers that focus on older adults and people with disabilities. Since ACOs are incentivized to be efficient care providers through the use of payments that reward improved care through collaboration, incorporating ASTs in their service provision presents an opportunity to improve quality and efficiency, especially if this is accompanied by adoption of health IT such as EHRs across care settings and interfacing ASTs with these health IT systems.

Also part of the ACA, the Medicaid Health Home state option allows states to enroll beneficiaries with two or more chronic conditions, including serious mental illness and substance use disorders, into health homes to enable coordinated treatment of their conditions. These health homes are designed to be person-centered systems of care that facilitate access and coordination of primary and acute physical- and behavioral-health care, and that provide long-term community-based services (Kaiser Family Foundation, 2011). The ACA specifically encourages and supports the use of health IT among health-home programs to facilitate their implementation and operation. This emphasis reflects the recognition that these programs and those they serve may derive particular benefits from the adoption of telehealth and behavioral-monitoring technologies, as well as from coordination and communication among the long-term and post-acute care providers that use them.

Coordinated research and development efforts and studies examining the efficacy and cost-effectiveness of ASTs can serve to stimulate uptake of these technologies among health plans and providers (National Council on Disability, 2000). Such studies can generate information about the effectiveness of various AST tools, their cost-effectiveness, as well as insight into shortcomings and areas requiring further development. Research on costs and benefits, both on an individual and a macro level, can also help support and justify investment in ASTs. Translational research is another valuable tool that focuses on incorporating efficacious technologies into best practices (Mahoney et al., 2007). Payers, including private health plans and long-term care insurance, are in a unique position to foster partnerships with providers, technology companies, and academia to evaluate the efficacy and cost-effectiveness of these technologies and technology-enabled interventions.

10.4. Barriers to Development

There are a number of barriers that inhibit the development of ASTs. These include limited actual market size and slow market growth rate despite the exceptionally large potential market for these technologies. The limited uptake, in turn, results in limited private-sector investment in technology development for this market and an accompanying lack of investment in robust research to generate definitive information on efficacy. In addition, there are significant up-front costs associated with both research and development of these technologies and bringing them to market. These include the cost and time associated with the cycle of development, efficacy testing, and FDA approval (where applicable), as well as cost-effectiveness studies and translational research efforts that are sufficiently compelling to change practice and consumer behaviors. These steps are time-consuming, funding is sparse and unreliable, and it is often the case that technology evolves faster than the ability of its developers to generate robust data. In addition, there are not many large-scale demonstration projects to generate compelling evidence of the benefits and cost-effectiveness of these technologies (LeadingAge CAST, 2008). If available, this type of information could be used to support marketing of these technologies and accelerate their adoption.

Potential Strategies to Address Barriers to Development of ASTs

A number of strategies have been proposed to address barriers to AST development. As noted above, limited market size and slow rates of adoption are limiting private-sector investment in ASTs. Thus, removing barriers to adoption and use among older adults, people with disabilities, and health-care providers is one way to increase the actual market size and start addressing this barrier. Growth in adoption would increase competition, decrease costs, and ultimately encourage private-sector investment in the development of more-advanced and better-designed ASTs.

Other strategies include organizing the industry market through professional consortia aimed at accelerating the development, validation, evaluation, and adoption of ASTs. Such consortia could foster partnerships between technology companies, aging services providers, and researchers; encourage user-centered design and development that engages the intended users; and conduct outcomes-oriented evaluations of ASTs in partnership with providers. Another approach is to identify and promote business and operating models that support the ability to design, implement, evaluate, optimize, and sustain technologies. These models could be used to encourage development of technologies that focus on “aging in place,” which is a basic element of the mission of many providers, health-care organizations, and technology developers. In this vein, one group has highlighted 18 case studies of innovative long-term and post-acute care providers that partnered with technology companies to develop and explore technology-enabled care models. These models include partnerships with hospitals to coordinate care for chronically ill individuals; low-cost private-pay insurance programs that guarantee the delivery of home-based life-care services supported by technology; and using continuing care retirement communities to deliver home and community-based services efficiently and cost-effectively using remote monitoring, medication management, and call center technologies (LeadingAge CAST, 2011b).

Another approach to spur the identification of innovative business models would be to create a “Grand Challenge” competition. This competition would ask technology developers and business schools to partner for the purpose of developing innovative business and operational models that use both existing and novel technologies, as well as a “road map” to implementing these models in order to help providers and break free from entrenched legacies. One possible forum for these partnerships may be challenge.gov, a website on which federal agencies present real-time policy problems or competitive challenges to the greater public and offer prize money and other incentives for the best submissions. The website aims not only to raise awareness among citizens, but also to foster collaboration and solicit creative solutions to important policy issues. This website could be an ideal forum for engaging technology and business experts in removing barriers to ASTs development and adoption.

Large employers can also act as a catalyst in the marketplace. For example, they could encourage health insurance providers to incentivize providers to use telehealth for beneficiaries (employees or family) or to redesign employee benefits programs to incentivize employees’ use of technology-enabled self-management, fitness, or other wellness activities. Another employer-based approach could involve caregiver support programs or educational resources that offer information to those serving in a caregiving role on available technologies and technology-enabled support services. Employers could also potentially negotiate discounts with pre-screened technologies or services as part of their employee benefits packages. These types of approaches would result in increased demand for ASTs, which in turn would encourage more investment and development.

Finally, creating both research opportunities to demonstrate the efficacy of ASTs as well as avenues for dissemination of the findings can play a key role in overcoming barriers to development (de Joode et al., 2010). This can be achieved through public-private partnerships that encourage private-sector co-investment in robust, large-scale studies to demonstrate both clinical effectiveness and cost-effectiveness of these approaches. These partnerships could include technology companies, private health insurance (e.g., Medicare Advantage and other capitated plans) and large health-care systems. Popular media and social media coverage are other effective dissemination tools that allow broader outreach to large groups of users, providers, and payers. The compilation and dissemination of evidence supporting AST adoption would ultimately increase market size and encourage investment in the development of new and improved technologies that spur innovation.

References

Abowd, G.D., Bobick, A.F., Essa, I.A., Mynatt, E.D., Rogers, W.A. (2002). The Aware Home: A living laboratory for technologies for successful aging. https://www.aaai.org/Papers/Workshops/2002/WS-02-02/WS02-02-001.pdf. Accessed April 4, 2012.

Agency for Healthcare Research and Quality (2003). Advance care planning: Preferences for care at the end of life. Rockville, M.D.: U.S. Department of Health and Human Services. AHRQ Publication No. 03-0018. http://www.ahrq.gov/research/endliferia/endria.pdf. Accessed April 4, 2012.

Agency for Healthcare Research and Quality (2008). Barriers and drivers of health information technology use for the elderly, chronically ill, and underserved. Rockville, M.D.: U.S. Department of Health and Human Services. AHRQ Publication No. 09-E004. http://www.ahrq.gov/clinic/tp/hitbartp.htm. Accessed April 4, 2012.

Balfour, D.C.III, Evans, S., Januska, J., Lee, H.Y., Lewis, S.J., Nolan, S.R., Noga, M., Stemple, C., Thapar, K. (2009). Health information technology--results from a roundtable discussion. *Journal of Managed Care Pharmacy*, 15(1 Suppl. A), 10-17.

Boissy, P., Choquette, S., Hamel, M., Noury, N. (2007). User-based motion sensing and fuzzy logic for automated fall detection in older adults. *Journal of Telemedicine and e-Health*, 13(6), 683-693.

Brownsell, S.H. (2004). Fall detectors: Do they work or reduce the fear of falling? *Housing, Care and Support*, 7(1), 18-24.

CAPSIL (2007). International support of a common awareness and knowledge platform for studying and enabling independent living. http://www.capsil.org/. April 4, 2012.

Center for Medicare and Medicaid Innovation Center (2012). The CMS Innovation Center. Baltimore, M.D.: Centers for Medicare and Medicaid Services. http://innovations.cms.gov/. Accessed April 4, 2012.

CNA (2010). Wireless Sensor Technology: Aging Services Applications and Associated Risks. http://www.cna.com/vcm_content/CNA/internet/Static%20File%20for%20Download/Risk%20Control/Medical%20Services/WirelessSensorTechnologyAgingServicesApplicationsandAssociatedRisks.pdf. Accessed April 4, 2012.

Congressional Research Service (2010). Medicare hospital readmissions: Issues, policy options, and PPACA. Washington, D.C.: Library of Congress. CRS Publication No. 7-5700. http://www.hospitalmedicine.org/AM/pdf/advocacy/CRS_Readmissions_Report.pdf. Accessed April 4, 2012.

Conner, K.O. (2008). Mental health treatment seeking among older adults with depression: The impact of stigma and race. *The American Journal of Geriatric Psychiatry,* 18(6), 531-543.

de Joode, E., van Heugten, C., Verhey, F., van Boxtel, M. (2010). Efficacy and usability of assistive technology for patients with cognitive deficits: a systematic review. *Clinical Rehabilitation,* 24(8), 701-714.

Fleming, J., Brayne, C. (2008). Inability to get up after falling, subsequent time on floor, and summoning help: prospective cohort study in people over 90. *British Medical Journal*, 337(7681), 1279-1286.

Gentry, T. (2009). Smart homes for people with neurological disability: State of the art. *NeuroRehabilitation*, 25(3), 209-217.

Gilly, M.C., Schau, H.J., Wolfinbarger, M.F. (2003). Seniors and the internet: Consuming technology to enhance life and family involvement. Home Oriented Informatics and Telematics (HOIT) Conference, 1-15.

Health Level Seven (2012). HL7 EHR system long term care functional profile, release 1 -- US realm. http://www.hl7.org/implement/standards/product_brief.cfm?product_id=134. Accessed April 4, 2012.

Kaiser Family Foundation (2011). Focus on health reform: Medicaid's new "Health Home" option. http://www.kff.org/medicaid/upload/8136.pdf. Accessed April 4, 2012.

Kim, J., Pape, T., Weiner, B. (2002). The shaping of individual meanings assigned to assistive technology: A review of personal factors. *Disability and Rehabilitation*, 24(1-3), 5-20.

Landau, R., Auslander, G.K., Werner, S., Shoval, N., Heinik, J. (2010). Families' and professional caregivers' views of using advanced technology to track people with dementia. *Qualitative Health Research*, 22(3), 409-419.

LaPlante, M., Kaye, S. (2010). Demographics and trends in wheeled mobility equipment use and accessibility in the community. *Assistive Technology*, 22(1), 3-17.

LeadingAge CAST (2008). State of technology in aging services according to field experts and thought leaders. http://www.leadingage.org/State_of_Technology_in_Aging_Services_According_to_Field_Experts_and_Thought_Leaders.aspx. Accessed April 4, 2012.

LeadingAge CAST (2011a). CAST analysis of state payment for aging services technologies (ASTs). http://www.leadingage.org/uploadedFiles/Content/About/CAST/CAST_State_Paymen_%20Analysis.pdf. Accessed April 4, 2012.

LeadingAge CAST (2011b). Preparing for the future: Developing technology-enabled long-term services and supports for a new population of older adults. http://www.leadingage.org/uploadedFiles/Content/About/CAST/Resources/Preparing%20for%20the%20Future_Case%20Studies.pdf. Accessed April 4, 2012.

Mahoney, D.F., Purtilo, R.B., Webb, F.M., Alwan, M., Bharusha, A.J., Aldam,T., Jimison, H., Turner, B., Becker, S.A. (2007). In-home monitoring of persons with Alzheimer's disease: Ethical guidelines for technology research and development. *Alzheimer's & Dementia: Journal of the Alzheimer's Association*, 3(3), 217-226.

Mandl, K.D., Szolovits, P., Kohana, I.S. (2001). Public standards and patients' control: how to keep electronic medical records accessible but private. *British Medical Journal*, 322(7281), 283-287.

National Academies Press. (2007). *Preventing medication errors: Quality chasm series*. Washington, D.C.: National Academies Press.

National Alliance for Caregiving (2011). eConnected family caregiver: Bringing caregiving into the 21st century. http://www.caregiving.org/pdf/research/FINAL_eConnected_Family_Caregiver_Study_Jan%202011.pdf. Accessed April 4, 2012.

National Council on Disability (2000). Federal policy barriers to assistive technology. http://www.ncd.gov/publications/2000/May312000. Accessed April 4, 2012.

National Research Council (1997). For the record: Protecting electronic health information. Washington, D.C.: The National Academies Press.

Popelka, M., Cruichshanks, C., Wiley, T., Tweed, T., Klein, B., R, K. (1998). Low prevalence of hearing aid use among older adults with hearing loss: The epidemiology of hearing loss study. *Journal of the American Geriatrics Society*, 46(9), 1075-1078.

Sirey, J.A., Bruce, M.L., Alexopoulos, G.S. (2005). The treatment initiation program: An intervention to improve depression outcomes in older adults. *The American Journal of Psychiatry*, 162(1), 184-186.

Spiro, R. (2008). Electronic prescribing in long-term care: An overview of five pilot projects. *The Consultant Pharmacist*, 23(1), 16-26.

U.S. Department of Health and Human Services (2006). What does the HIPAA privacy rule do? Washington, D.C.: U.S. Department of Health and Human Services. http://www.hhs.gov/hipaafaq/about/187.html. Accessed April 4, 2012.

Veldhoven, E., Vastenburg, M., Keyson, D. (2008). Designing an interactive messaging and reminder display for elderly. 2nd Annual European Conference on Ambient Intelligence, 126-140.

Vogelsmeier, A.A., Halbesleben, J.R., Scott-Cawiezell, J.R. (2008). Technology implementation and workarounds in nursing home. *Journal of the American Medical Informatics Association*, 15(1), 114-119.

Wasson, G., Sheth, P., Huang, C., Alwan, M. (2008). Intelligent Mobility Aids for the Elderly. In M. Alwan, R. Felder. *Eldercare Technologies for Clinical Practitioners*, 53-76. New York, New York: Humana Press.

Yu, H., Spenko, M., Dubowsky, S. (2003). An adaptive shared control system for an intelligent mobility aid for the elderly. *Autonomous Robots*, 15(1), 53-66.

CONCLUSION

Many care issues affect older adults and people with disabilities (and therefore, their caregivers and service providers). These issues vary in terms of their effect on these groups' health and well-being, and the resultant costs and burdens. The care issues addressed by this study affect a large number of one or more of these groups, and/or incur large costs or burdens on them and the health-care system.

As age increases, so does the occurrence of numerous chronic conditions that can have a profound impact on the health and well-being of not only older adults who are affected by these conditions, but also informal caregivers who provide extensive support to affected individuals. These conditions, as well as disabling injuries, result in multiple, complex care issues that can cause significant challenges to maintenance of health, functioning, and independence. These care issues range from difficulties associated with engaging in appropriate disease management activities and managing medications to increased risk of falls and depression.

Eight care issues were the focus of the initial chapters of this report. These care issues share some common features, including high prevalence and cost. For instance, one-third of adults age 65 and older experience a fall each year and 27 percent have diabetes. Among all adults, one-third have uncontrolled hypertension and 75 percent report not taking their medications as prescribed. Thirty-seven percent of people age 90 and older have a diagnosis of dementia. The high prevalence of these problems translates into significant challenges not only for patients, but also for health-care providers and informal caregivers who support these individuals.

In addition to their high prevalence, the care issues discussed in this report are associated with extremely high costs. Falls are estimated to cost more than $28 billion annually, medication errors are associated with an estimated $290 billion in avoidable medical expenditures, and treatment of Alzheimer's disease and dementia costs $183 billion each year. Given the high prevalence and costs of these care issues, implementation of cost-effective approaches to reducing the occurrence or severity of these problems could have a substantial impact on the health of affected individuals as well as the costs associated with their care.

Although they share a number of similarities, these care issues also differ in important ways, particularly in terms of the specific challenges that they pose to patients and caregivers. For example, challenges with medication management often involve the ability of both patients and caregivers to monitor and ensure compliance with daily dosing regimens, whereas depression may involve efforts to maintain and promote social interactions, and dealing with cognitive impairment is frequently associated with the need to monitor patients' movements to prevent wandering or other dangerous behaviors.

These care issues are not only complex in terms of the specific problems they pose to patients, providers, and caregivers, but they are often interrelated with one another in ways that directly affect numerous aspects of health and well-being. For example, an older adult with cognitive impairment may not only be dealing with memory problems, but also with difficulties remembering to take their medications. If their cognitive impairment is severe, it may also result in depression and social isolation because they are no longer able to make effective use of their social networks. Additionally, functional decline or impairments that reduce mobility may contribute to increased falls among older adults, as they lose their ability to move independently and maintain balance. Moreover, these individuals may receive uncoordinated care from multiple community-based health-care providers, and may transition among care settings in response to acute health events, such as falls.

Advances in computing and communications technologies have led to the development of aging services technologies (ASTs) aimed at addressing these and other care issues that are common among older adults and people with disabilities. The specific impacts that these care issues have on patients and caregivers, as well as providers' growing need for access to timely, tailored patient information that provides insight into these specific problems has resulted in the development of a wide array of ASTs that seek to address one or more of the care issues explored in this report. Some of these ASTs are designed for consumers (i.e., older adults, persons with disabilities, or their caregivers), others target health-care professionals, and still others are meant to be used by both. Medication management technologies are an example of consumer-focused products; computerized physician order entry (CPOE) is an example of a provider-focused technology; and remote patient monitoring (RPM) technologies serve both by transmitting patient data to providers for review and interpretation. As a result, some ASTs are utilized primarily in the community, some in provider settings, and some in both. Further, some of these technologies aim to detect the signs of unfavorable health symptoms, some aim to prevent onset or progression of disease, and others focus on treatment.

Numerous consumer-focused ASTs are available to address these complexities and many either interact with or have the capacity to interact with forms of health information technology (IT) such as electronic health records (EHR) that are maintained by providers. Understanding the interplay of ASTs and health IT is important because it provides insight into how the full capacity of both ASTs and health IT can be realized to support the needs of older and disabled individuals. Despite the great potential for ASTs to enhance quality of life and independence, development and adoption have been slow and, for some technologies, sustained use among adopters is challenging. Nonetheless, a number of strategies are available that can begin to address these barriers and promote increased development, adoption, and use.

Problems Addressed by Aging Services Technologies

The care issues addressed in this report are associated with an extensive array of problems affecting not only affected individuals (older adults and persons with disabilities), but also the caregivers and health-care providers who provide formal and informal support for them. This study shows that ASTs address a wide variety of problems, some of which are specific to a particular case issue, while others are more general and cut across multiple care issues. As a result, some ASTs are discussed in more than one chapter. For instance, remote monitoring technologies are applicable to a number of care issues in this report and are discussed in the chapters dealing with falls, chronic disease management, and functional decline.

It is generally the case that the specific problems that ASTs address are more varied for affected individuals than they are for providers or caregivers because more ASTs are marketed to, and meant for use by, these individuals than providers or caregivers. For example, a multitude of consumer-focused technologies are currently available for cognitive training, medication management, self-monitoring of physical activity, and chronic disease management. Although there are numerous technology products targeted at providers, these are often large, multi-function systems such as computerized physician order entry (CPOE), computerized decision support (CDS), or electronic health records (EHR), rather than technologies that address specific care issues.

A common problem for many older adults and people with disabilities is a lack of timely feedback on health conditions and risk factors relevant to their clinical and behavioral profiles. The absence of up-to-date, relevant information can inhibit individuals from effectively engaging in risk-reducing or health-promotion behaviors that help them remain independent in the community. Many ASTs are equipped to provide individuals with ongoing information feedback on activities and behaviors related to these care issues. For instance, chronic disease management technologies can provide real-time feedback to users on blood glucose levels and blood pressure, falls prevention technologies help users in ongoing self-monitoring of abnormalities of gait and balance, and medication management technologies provide users with reminders and prompts that help them stay on schedule with their medications. All of these technologies share the goal of providing information on a continuous basis so that users can be more effective in managing their conditions and identifying when risk factors change in a way that signals the need to contact a caregiver or health-care provider. Similarly, basic internet access, as well as social networking sites for older adults and people with disabilities facilitates connections with friends, family, and peers in ways that help maintain and build social networks. The benefits of these technologies cut across many care issues by enhancing social connectedness and overall quality of life, two factors that are often compromised among individuals in these populations.

Just as ASTs seek to provide individual users with improved feedback using relevant data, these technologies can also address common problems experienced by caregivers. These problems include the lack of real-time information on a patient's health status, difficulties in maintaining adequate communication with the patient, and challenges associated with being able to identify behavioral or other changes that might signal the need for additional supportive services or other changes in care planning. For example, medication and chronic disease management technologies as well as various RPM technologies have the capacity to transmit data to a family member who is active in informal caregiving. This information directly addresses caregivers' lack of access to timely information on their loved ones, and often permits them to engage in certain caregiving activities without having to be physically present with the individual in need of care.

Among the most common problems that ASTs address for providers is lack of access to reliable, longitudinal, and clinically relevant patient data between office visits. Telehealth, and in particular, RPM are examples of ASTs that not only address these basic issues, but that also have implications for a variety of care issues such as chronic disease management, falls prevention, and depression. These technologies allow providers to connect with patients, capture relevant data on an ongoing basis, and give feedback to patients in a manner that helps them to maximize their self-management capacity. Another important feature of some ASTs involves their ability to interface with provider-based health IT such as EHRs, electronic prescribing, CPOE, and CDS systems.

In contrast to some of the broad, cross-cutting ASTs reviewed in this report, others provide support to patients and caregivers that is highly specialized. Examples of these technologies include cochlear implants for hearing impairments and neuromuscular stimulation for addressing decrements in balance. These technologies tend to be less widely applicable, and some involve implantation, or other "invasive" approaches to utilization.

Currently Available Technologies

The study shows that a large and diverse variety of technologies are currently available to address many of the common problems faced by older adults and persons with disabilities who are dealing with the care issues highlighted in the report. While some of these technologies are highly specific and focus on one or a few elements related to a single care or functional issue, others approach these care issues with broader approaches to technology-enhanced support for users and caregivers. One way to think about currently available technologies is to consider the groups and settings that are the primary targets of specific products or technologies. Although this approach to considering ASTs does not result in mutually exclusive categories, it is nonetheless a convenient way to consider ASTs that are currently available in the marketplace.

Consumers

This report finds that there are many ASTs targeted to consumers, and in particular to older adults, persons with disabilities, and their caregivers. These technologies include implantable and other medical devices, software products, monitoring systems, assistive devices, social media, and smart home systems.

There are a wide variety of technologies that are delivered to consumers in "device" form. Examples include table-top medication management dispensers, devices that allow tracking of glucose, heart rate, and physical activity, hearing aids, and wearable devices that permit self-monitoring of physical activity. There are also a number of AST devices that can be considered more invasive, some of which, like cochlear implants, involve surgical implantation.

Numerous software products are aimed at older adults, and many of these focus on cognitive or memory training. Similarly, the internet offers many online communities and social media aimed at promoting interactions among older adults and those with disabilities. Other ASTs leverage assistive devices like canes, walkers, and wheelchairs. These technologies often involve sensors that collect information on movement or on the user's location. There are also ASTs that involve sophisticated home-monitoring systems that can collect information ranging from activity and sleep patterns to abnormalities of gait and balance. Finally, smart home systems feature complex, technology-enhanced approaches to facilitating routine activities that help maintain independence.

These devices are designed primarily for use in the community. However, many technologies that are oriented toward consumers have features that permit transmission of information to caregivers, thereby facilitating caregivers' ability to support users. Caregivers can capitalize on AST functionality by monitoring factors as diverse as blood pressure, sleep patterns, social connectedness, medication adherence, and appliance use.

Providers

Older adults and persons with disabilities receive services in multiple settings, including hospitals, nursing homes, and home health agencies. Some of these settings have, or plan to adopt, technologies such as EHRs, CPOE, CDS, telehealth applications, and electronic prescribing. Ideally, these technologies assist providers in maintaining accurate health information on their patients while simultaneously facilitating access to decision support and reducing medication and other errors. Although some of these technologies have the potential to interface with ASTs in ways that result in synergies for patients and providers, interoperability and other challenges have made these synergies difficult to implement in practice. Developing interfaces that are compatible with multiple technologies will be a key step toward making these monitoring technologies especially effective.

Aging Services Technologies That Address a Diversity of Care Issues

There is evidence to suggest that ASTs hold promise for addressing specific problems associated with a number of the care issues examined in this report. There are multiple examples of how these technologies provide meaningful support to patients, including provision of more and higher-quality health information, better ways to remain connected with caregivers, peers and health-care providers, as well as provision of tailored support that addresses specific features of absent or declining function. However, the published evidence supporting the benefits of ASTs is heterogeneous, with some ASTs having extensive evidence supporting efficacy and efficiency (e.g., technologies for monitoring of congestive heart failure) and others having more limited available data that support their benefits (e.g., online social networks aimed at reducing social isolation). Thus, the extent of the evidence presented for various technologies that address specific care issues varies from chapter to chapter.

Using medication management as an example, the research shows that currently available medication management technologies can address a number of specific and general health-care problems, including organizing and dispensing of medications (and therefore directly treating a care issue), as well as the provision of reminders and feedback on medication compliance (thereby helping to prevent future problems). These technologies also address general problems including collection of clinically relevant, longitudinal information that can be transmitted to informal and formal caregivers and providers to help them be more effective in supporting the patient. Further, these technologies have the capacity to upload information to personal health records, highlighting their ability to interface with health IT. These technologies also allow health information that may be pertinent across a number of health issues to be collected and available for consideration by both patients and doctors, thus allowing patients to be provided with meaningful and tailored supports that directly benefit health, while also potentially reducing caregiver burden and increasing providers' access to timely, relevant information.

The potential benefits to key stakeholders offered by medication management technologies can also be imparted through the use of other ASTs. Fall prevention and chronic disease management technologies, such as bed sensors, have many of these potentially far-reaching benefits, and their efficacy in addressing specific care issues is further enhanced when they are integrated with health IT. Additionally, certain technologies such as those that assist with medication management may help address a variety of care issues such as falls, functional decline, and depression. Other technologies such as software that reduces social isolation among older adults may also alleviate depression.

Evidence of Efficacy and Cost-Effectiveness

There is a great degree of variability in the amount and quality of evidence supporting the efficacy and cost-effectiveness of ASTs. In some cases, the evidence supporting certain ASTs' benefits is compelling, but for many, there is a lack of high-quality research supporting their clinical benefits and cost-effectiveness. For instance, multifactorial interventions for fall prevention that include health IT have been shown to be especially effective in reducing hospital-based falls. These interventions can include technologies aimed at increasing physical activity and those that alert health-care professionals when patients are engaging in high-risk movements that signal increased fall risk. Telehealth offers another example of an AST for which strong evidence of both efficacy and cost-effectiveness are available, particularly in Veterans Administration (VA) settings. A telehealth program instituted by the VA for the care of older patients with common conditions such as diabetes, hypertension, and COPD led to a 25 percent reduction in bed days and a 19 percent reduction in hospital admissions and re-admissions. The telehealth intervention also led to substantial cost savings, and had an 86 percent patient satisfaction rate.

Telehealth and RPM have been shown to be effective in reducing unfavorable outcomes in heart failure patients and there is evidence to suggest that they are also effective in managing diabetic patients. Telemonitoring also appears effective in improving certain outcomes among individuals with hypertension and COPD. Finally, telemental health technologies are supported by considerable evidence supporting their efficiency, cost-effectiveness, and their role in the provision of high-quality mental-health services.

Passive activity-monitoring technologies, coupled with professional care services, have shown the ability to detect incipient health issues early on, facilitating the coordination and delivery of care services that support independence. These technologies have shown promise in improving care recipients' quality of life when used by professional caregivers, reducing professional caregivers' burdens, reducing the cost of care, and allowing older adults to move out of nursing homes and into housing with service settings. However, larger and more longitudinal demonstrations can help establish more definitively their efficacy, cost-effectiveness, and ability to prolong independence.

Health IT applications such as CDS and CPOE have been shown to reduce medication errors in hospital settings, and electronic prescribing is effective in reducing medication errors in outpatient, inpatient, and intensive care settings. Additionally, certain sensory impairment technologies are very effective at restoring the impaired sense at least to some extent. Hearing aids and other implants are generally very effective in terms of allowing older adults to regain some of their sense of hearing. Technologies that convert text into speech, whether from a cellphone, computer, or other device, allow older adults with visual impairments to successfully use these devices.

Despite the availability of evidence supporting the benefits of certain ASTs, others do not have compelling, and sometimes any, data supporting either their clinical efficacy or their cost-effectiveness. Many of the ASTs that lack this type of information are those targeting consumers and caregivers who seek to address issues related to cognitive impairment. Although a number of technology-enhanced products aimed at cognitive training are available, randomized studies of these approaches are limited, and often absent. While some ASTs aimed at cognitive training appear to show benefits for short-term memory training, long-term, sustained gains in memory have not been definitively demonstrated, and sustained use of these products appears necessary to maintain early gains.

Online social networks have been proposed as a technology-enhanced means of maintaining social connectedness, particularly among older adults who experience cognitive decline. However, the efficacy of these approaches for preserving cognitive function has not been demonstrated. Similarly, certain ASTs embedded in the home are designed to identify activities and movements that are indicative of mild cognitive impairment and dementia, but practical implications of this information for the provision of clinically relevant benefits has not yet been established. A similar lack of demonstrable benefits applies to caregivers of these individuals. For example, although some online support systems are designed to promote communication and reduce caregiver burden, the extent to which these benefits are realized by caregivers, and whether they reduce the well-documented physical and emotional strains of caregiving, have not been fully demonstrated.

Technologies Under Development

In addition to ASTs that are currently available, a wide variety of technologies are in various stages of development. Most development activities are based in universities or small start-up ventures. Some technologies under development offer improvements to existing products, while others are novel approaches to addressing the care issues explored in this report.

One class of emerging technologies offers improvements in RPM, including innovations in both wearable and embedded devices. Innovations in fall detection systems involve linking cellular communications devices to emergency call centers or informal caregivers. It is likely that innovations in monitoring technologies will continue to evolve in tandem with the evolution of personal cellular technologies. Further, the penetration of cellular technologies among younger adults will increase the likelihood that, by the time these individuals reach old age, they will be more likely to accept supportive services linked to cellular devices.

Evolution in medication management technologies aims to make delivery of reminders more acceptable and useful to users by sending reminders based on the most favorable context, rather than based simply on clock time. Technologies that incorporate tailored approaches to providing targeted supports may be increasingly in demand in the future as technology-savvy consumers demand products that are not only effective in their primary function, but that are both flexible and personalized. In the future, approaches to delivery of medication reminders is likely to become increasingly linked to personal electronic devices because younger adults will have "aged in" using these devices for a wider variety of tasks than will have older adults today.

Assistive devices such as canes are also the target of AST development. New cane and walker technologies that are instrumented with sensors seek to integrate and stream data from sensors that measure motion, force, and other parameters using Bluetooth or Wi-Fi technologies. These data can be transmitted to a clinician who can use the information to modify care plans if data suggest an imminent fall risk. These technologies may be appealing to older adults because they have the potential to offer meaningful improvements on a familiar and accepted assistive device that is already widely utilized. The importance of assistive devices aimed at maintenance of ambulation cannot be overemphasized because loss of this ability is among the strongest risk factors for loss of independence. Thus, ASTs that can be effectively integrated into common devices such as canes and walkers may have a particularly strong impact on maintenance of independence.

AST development is leveraging existing technologies like global positioning systems to make new products that fill gaps in the market. New technologies aimed at monitoring wandering behaviors among older adults with cognitive impairment are capitalizing on GPS technology to develop new approaches to provision of caregiver support for this serious issue. Wearable systems that combine GPS and cellular technologies have the potential to increase safety and prolong independence among cognitively impaired adults. They also provide substantial support to overburdened caregivers who are often the only resource that lies between an older adult with dementia and loss of independence in the community. The ability of a remote caregiver to track a loved one over his or her home computer using GPS technology has far-reaching implications for the ability of these caregivers not only to preserve the independence of loves ones, but also to substantially reduce both the direct and indirect costs associated with their caregiving.

In contrast to ASTs that offer improvements to existing approaches or products, other technologies offer novel strategies to approaching various aspects of the care issues explored in this report. In general, these new technologies tend to be highly specialized, and often involve implantation or ingestion. Sensory impairments and medication management technologies offer examples of these trends. Novel technologies in these areas involve replacement of deficient structures in the eye and ear with implantable devices such as telescopes, retinas, and cochleas. These devices aim to address very specific sensory issues and are less focused on transmission, review, or monitoring of clinical information, and integration of sensory data with health IT than the other ASTs this report describes. Although they might ultimately prove to be highly effective for some kinds of sensory impairments, novel technologies that are highly specialized and require surgical implantation may not be utilized by large audiences due to cost, lack of access to specialists who conduct the procedures, and a general aversion to elective surgery when viable alternatives are available for lower cost. Further, the invasive nature of these technologies will require extensive clinical testing and high up-front costs, considerations that have important implications for when these products may ultimately make it to market. Similarly, novel medication management technologies include pills that have tracers or dyes that help ensure that medication has been ingested, and in some cases, that facilitate tracking of physiologic responses to the medication after it has been ingested. These evolving technologies are notable in that they have the potential to indicate that medication was actually ingested, a meaningful step forward over existing technologies that indicate only that medication has been dispensed.

Technologies Available Outside the United States

This study finds that ASTs that are currently available in other countries are also available in the U.S. with few exceptions. However, some technologies are implemented more widely and effectively outside the U.S., particularly in the European Union (EU). As a result, some technologies such as fall detection and prevention systems, personal emergency response systems, technologies that address cognitive impairments, and telehealth technologies have greater penetration than they do in the U.S. Other technologies have emerged in response to the need for access to health information for EU citizens who travel frequently across EU borders. A key feature of these health IT and other EU-based AST initiatives is the existence of EU consortia and technology-oriented collaborations that have an interest both in moving AST development and implementation forward, as well as in integrating these technologies with health IT.

Barriers to Development, Adoption, and Sustained Use of Aging Services Technologies

Despite the array of ASTs that are currently available and under development, there are various barriers that inhibit development, adoption, and sustained use of these technologies. Some of these barriers relate primarily to consumers and caregivers while others impact providers. Some barriers relate specifically to payers and still others pertain to factors that inhibit development of new ASTs. This study focuses on barriers outside of the financing context.

Among the most far-reaching barriers to AST adoption among consumers is lack of awareness, on the part of both patients and providers, of available ASTs. This lack of awareness relates in large part to ASTs that are targeted for home or personal use by affected individuals and their caregivers. This barrier acts to inhibit demand for ASTs on the part of users, and impacts informal caregivers who often take active roles in medical decision-making for loved ones. The general absence of widespread knowledge concerning available technology solutions results in an under-developed market for these technologies despite the well-recognized growth of the older population in the U.S. Lack of AST awareness is also present among physicians and other health-care professionals who are in key referral positions, including discharge planners and geriatric social workers. Professional associations and scholarly journals do not focus heavily on the role of ASTs in patient care, and the lack of peer-reviewed data disseminated in these forums results in limited knowledge on the part of providers regarding not only the availability of ASTs, but also the evidence base supporting their efficacy. Thus, although ASTs are widely available in the U.S., they are underutilized in part due to the combined lack of knowledge on the part of all key stakeholders, including patients, providers, and caregivers.

Another barrier to AST adoption and use involves concerns on the part of both consumers and providers that privacy and security may be compromised when using these technologies. Among consumers, increased attention has focused on these issues in part as a result of frequent media coverage of data breaches, hacking, and theft of personal information. Many consumers also have personal experiences with email scams and other technology-associated incidents that affect their confidence in the ability of others to act as responsible stewards of sensitive information. These issues contribute to consumers' concerns about the security of their health data and the extent to which they can trust others with stewardship of sensitive information. These concerns extend to consumers' willingness to use ASTs, and particularly technologies that transmit information or interface with health IT.

Data privacy concerns that inhibit uptake of ASTs are not limited to consumers. Although these concerns were addressed by strict data-handling regulations under HIPAA, some technologies were not designed with adequate privacy and security safeguards in place to protect the information they collect. As a direct consequence of these security concerns, many providers shy away from adopting certain technologies out of concerns about non-compliance with federal regulations.

There are additional barriers to AST development that relate specifically to payers. Although there are notable exceptions, financial incentives are not currently aligned in a manner that encourages most public and private insurers to cover the services that are provided by ASTs. This impacts demand and contributes to the ongoing cycle of under-development of the AST marketplace. Moreover, improvements to existing ASTs, as well as development of novel ones, require a strong market and market growth, two factors that are also currently under-developed. These challenges result in low investment, which, when coupled with high up-front costs, limits both development and innovation.

Strategies to Facilitate Development, Adoption, and Sustained Use of Aging Services Technologies

Strategies that may be effective in addressing barriers to development, adoption, and sustained use of ASTs are as diverse as the barriers themselves, with some focusing on consumers and caregivers and others relating to providers, payers, and factors enabling AST development.

Lack of awareness of ASTs is a cross-cutting barrier for a number of key stakeholders and effective strategies for addressing this barrier may be one of the most promising approaches to expanding AST use more generally. Methods for improving awareness include provider-oriented activities aimed at increasing dissemination of high-quality, peer-reviewed data on the effectiveness of ASTs. This can be accomplished with vehicles such as peer-reviewed journals, professional associations, continuing education activities, scientific meetings, and popular and social media campaigns. Effective use of these existing, provider-focused information delivery mechanisms could increase patient demand for ASTs if the information delivered to providers affects the likelihood of their recommending AST use--and of patients and caregivers following such recommendations.

Additionally, focusing information dissemination efforts on existing organizations oriented toward the provision of services for older adults and persons with disabilities may be an effective strategy for improving AST use. These organizations include social service agencies, Area Agencies on Aging (AAAs), University Centers for Excellence in Developmental Disabilities (UCEDD), and other, similar organizations. There are thousands of these organizations across the country, and with focused efforts to educate clients and caregivers about available ASTs, they hold a great deal of promise for increasing awareness of these technologies. Existing networks of community-based senior centers and disability support agencies could engage in similar education programs for their clients and their infrastructure could be leveraged to promote both awareness and utilization of ASTs.

Strategies that address payment-related barriers could aim to better align incentives in a manner that encourages providers to adopt ASTs. These could involve leveraging features of the Affordable Care Act (ACA) related to incentives for preventable hospital readmissions as well as incentives to improve chronic care management in diverse settings. Other ways to align incentives to promote AST adoption beyond hospitals could involve accountable care organizations (ACOs). These organizations include long-term care and home and community-based services, in addition to hospitals or physician groups, and are incentivized to provide high-quality, efficient care. To the extent that ASTs, and the interface of ASTs with health IT, help ACOs achieve their goals, they may be attractive options for these organizations.

A fundamental barrier to AST development remains the limited market for these products despite an expanding potential consumer base. It follows that increasing market size will help foster the investment that will fuel development and innovation. In this context, a number of strategies could be explored to promote growth. These include organizing consortia the goals of which are to foster partnerships among technology companies, aging services providers, disability service providers, and researchers, all with the common goal of generating high-quality products and expanding the market. Other approaches to encourage development include identifying ways that large employers could create demand for these technologies through incentive programs or employee benefits that encourage use of ASTs. Finally, identifying business models that communicate a clear return on investment would create further demand and foster development.

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