A Usability Framework for the Design of Assistive Technology to Promote Aging in Place

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ABSTRACT
A usability framework is proposed for designing assistive technology that meets the needs of older adult users. The framework is comprised of both requirements and profile components. The requirements component focuses on requirements specification from the perspective of technology, utility, and usability. The profile component encapsulates user requirements in terms of personal characteristics, normal aging factors, chronic health conditions, and other user characteristics that need to be accounted for in the design of assistive technology.

1. INTRODUCTION
Extraordinary societal changes in the U.S. have taken place in recent decades from both human and technological perspectives. Life expectancy continues to increase due to improvements in both medical care and technology. Older adults, 65 years plus, comprise 12.4% of the U.S. population with about one in every eight Americans being in this age group (U.S. Administration on Aging, 2002). By 2030, the percentage will have increased to 20% of the total population representing twice the number as in 2000. Those 85 years and older represent the fastest growing group (He, et al., 2005).

Information and communication technologies (ICT) have entered a new era of automated support through assistive technologies. The U.S. Administration on Aging (2005) defines assistive technologies as being services or tools that help the elderly or disabled do the activities they have always done but must now do differently. These technologies often determine whether a sixty years or older adult is able to live independently or must move to an institutionalized environment. Many older adults view quality of life as being dependent on aging in place in their own homes (Population Reference Bureau, 2002). This is reflected in 83% of older adults owning their own homes (Gitlin, 2003), even though 58% need help with daily living activities (U.S. Department of Health and Human Services, 2001). Given their stage of life, many seniors are motivated to hold onto a home for as long as possible (Sneeding, et al., 2006).

Research in assistive technologies is needed to promote aging in place with a focus on independent living and control over everyday activities. This includes automated support for managing medication, performing daily tasks, staying socially active, supporting cognitive functions, and maintaining a healthy diet, among others. With these support systems in place, older adults not only have an opportunity to stay in their homes longer but to improve the overall quality of their lives.

Research efforts in assistive technologies have been ongoing for several decades. But, it appears that a lack of commercialization persists in turning research outcomes into viable products. Smart homes, for example, have been studied since the early 1990's. Yet from a practical point of view, it is difficult to assess the benefits of smart homes in achieving aging in place objectives. Hurst et al. (2005) suggest that not only is there resistance in product development but also user resistance. From an older adult perspective, expense, invasiveness, lack of control, complexity, difficulty in operations, and lack of aesthetic appeal impact the acceptance and use of technology. Many older adults have already conceded control over various aspects of their daily living to family, friends, and healthcare personnel. They resist conceding control to technological devices that are viewed as invading privacy and lack perceived personal utility to warrant their use.

An understanding of diversity issues associated with aging is needed in order to develop assistive technologies that are universally accessible. To achieve this, usability factors associated with aging and chronic illnesses need to be accounted for in the design of such technologies. This requires a comprehensive understanding of the targeted user group and technological opportunities as well as constraints.

We present a usability framework that became the basis for designing assistive technology as part of an ongoing research project. The design objective was to account for user diversity associated with aging adults often burdened by caregiving responsibilities.

2. BACKGROUND
There is widespread agreement that assistive technologies offer great potential in dealing with quality of life challenges for an aging population. Older adults face physiological changes that increasingly impact daily living. These changes affect vision, cognition, hearing, and motor skills.[1] Figure 1 shows the degradation of vision due to normal aging illustrating one of the many technology design challenges. In order to produce technologies that meet the needs of older adults, it would be important to integrate aging considerations into the design process. Yet there are few guidelines for designing technologies for older adults with and without chronic health conditions. The U.S. National Institute on Aging (2001) offers guidelines for senior-friendly Web sites, this is a step in the right direction. However, more research is needed to address universal access of assistive technologies for an aging population.

Forty percent of older adults over 70 years of age deal with one or more chronic illnesses that affect daily living (Nehmer et al., 2006). Table 1 shows the percentage of the U.S. aging population suffering from chronic conditions. The significance of this data is that chronic illnesses are relatively pervasive in the aging population; and as such, have to be taken into account during the design of assistive technologies. Arthritis, Fibromyalgia, and other neuromuscular diseases, for example, may affect the use of data entry mechanisms due to degraded finger and hand dexterity. Type II diabetes may affect readability of text presented in a small font size due to

Figure 1. Simulation of the impact of aging vision. (Degradation in visual acuity affects ability to see objects clearly, thickening of lens impacts color perception, and decreased light sensitivity affects adaptation to changes in light levels (American Foundation for the Blind, 2004))

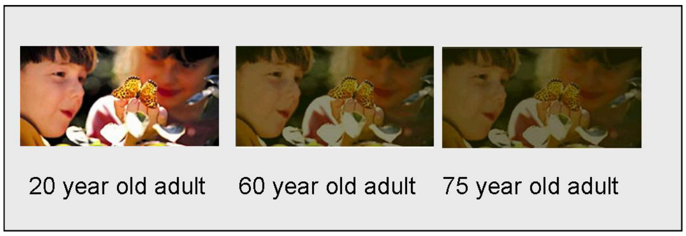


Table 1. U.S. Health and Human Services (2004) statistics on chronic conditions for older adults 65 years plus

Chronic Condition	Percentage
Hypertension	51.9
Arthritis (as diagnosed by doctor)	50.0
Chronic joint systems	46.0
Heart disease	31.8
Cancer	20.7
Diabetes	16.9
Stroke	9.3

lost peripheral vision. Alzheimer's disease[2] may impact cognitive abilities needed for recall of complex tasks associated with using assistive devices.

Figure 2 illustrates two different designs for a PocketPC screen --one of which is a standard user interface. The keyboard design, shown on the left, is part of Microsoft's Windows Mobile 5.0 software system. Data entry on this keyboard requires the use of a small stylus pen with a high level of accuracy in order to successfully tap a targeted key. Due to vision and motor skill degradation, older adults may experience difficulty using this user interface and data entry mechanism. Those older adults suffering from chronic or age-related illnesses with impacts on vision and motor skills may find this keyboard design virtually impossible to use.

The keyboard interface, shown on the right, has been designed as part of our research with input from older adult subjects. The keyboard can be switched to an alphabetical one with even larger key sizes to accommodate vision and physical impairments. (The alphabetized keyboard is not shown in Figure 2.) The senior-friendly design was intended to support the use of finger tip or fat stylus pen to perform a data entry task[3]. Thus, the PocketPC keyboard could be used by older adults to support daily living activities; such as making lists, composing email messages, and setting reminders, among others.

Gregor et al. (2002) have developed the concept of Design for Dynamic Diversity (DDD) when addressing the usability issues associated with the aging population. They suggest that the development of accessible interfaces is unique and a multi-faceted challenge given the diversity of the targeted user group and its

Figure 2. User interface design as part of the assistive technology research project

ever-changing needs (p. 151). They have developed an informal taxonomy of older adult users that includes: healthy older adults, older adults who are frail due to age-related disability, and disabled older adults who suffer from chronic illnesses. This taxonomy allows for the characterization of user groups based on normal aging factors and the impact of both age-related and chronic diseases. We integrate this taxonomy in a usability framework to support our assistive technology research project.

3. USABILITY FRAMEWORK

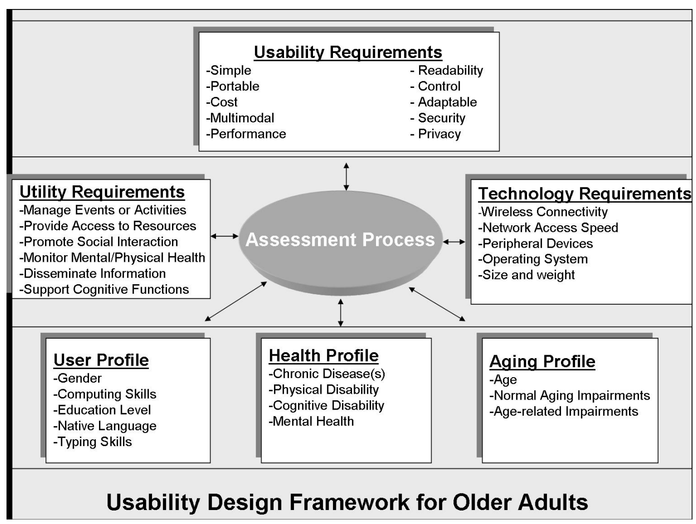
The framework proposed in this paper is an expanded version developed by Becker et al. (2000) whereby user and technology characteristics became part of the system requirements. User characteristics, in the original framework, included age, gender, computing experience, education, and typing skills. The technology characteristics included browser type, network access speed, screen size, and specific data entry mechanisms, among others. These characteristics ensured that software applications accounted for hardware and software constraints that if unknown might impede usability by targeted users.

The usability framework includes a comprehensive set of requirements to support the design of software applications as part of our assistive technology research project. These PocketPC applications bundled together are called PocketBuddy; and they target a diverse group of older adult caregivers. The intention is that PocketBuddy, with novel user interface designs, would provide automated support for managing medication, reporting on daily activities, scheduling appointments, monitoring a loved one for whom care is provided, promoting social interaction, and disseminating information.

Framework components were formalized through usability studies involving older adult subjects ranging in age from 65 to 90 years. Feedback from health-care personnel, working closely with older adult subjects, also provided insight regarding factors that might impede or promote usability. Early in the research, it was determined that the framework would encompass the usability needs of older adults who are homebound, isolated, and burdened with caregiving activities in order to promote universal access. It would also capture usability requirements associated with vision, cognition, hearing, and motor skill degradation associated with normal aging; and as much as possible, degradation due to age-related illnesses and health conditions.

Figure 3 shows the framework decomposed into two major components. The requirements component focuses on requirements gathering from the perspective of technology, utility, and usability. The profile component encapsulates user requirements in terms of personal characteristics, normal aging factors, chronic health conditions, and other user characteristics to be accounted for in the design of assistive technologies.

Figure 3. Proposed usability framework used in the design of PocketBuddy



3.1 Requirements

Usability Requirements

The usability framework shows a set of requirements used in the design of PocketBuddy technology. In our design of a timer application, portability became a usability requirement to promote usage within and external to the home environment. The timer application had a multimodal requirement to ensure events are made known to the older adult as they fire. Audio support, as part of the multimodal requirement, accounted for normal hearing loss associated with aging through the design of appropriate sound frequencies, melody lengths, and volume. A readability requirement accommodated aging vision such that content was highly visible while taking into account screen size. The readability requirement also ensured appropriate use of foreground and background colors to maximize content visibility while accounting for screen glare.

Each of the usability requirements in the framework is further described from a more general perspective.

Simple – This requirement encompasses user recall after initial training and when the technology is not used regularly. The required learning curve must be minimal in order to provide utility to an older adult user. Complex technologies with long learning curves are often not well accepted by adults in later stages of life.

Portable – Portability requirements ensure that technology components are lightweight, readily found when misplaced, and easy to handle if transported by an older adult user. To promote portability, few or no installation or setup requirements are needed when the technology is used in alternate settings.

Cost – Cost requirements ensure that assistive technologies are affordable to those on fixed incomes inclusive of reimbursement potential through federal, state, or private healthcare resources. Affordability and reimbursement requirements would include the cost of licensing, software maintenance and upgrades, and support services.

Multimodal – Multimodal requirements support multiple mechanisms for relaying information to an older adult user. Vision, hearing, cognition, and motor skill degradation associated with both normal aging and chronic conditions would be taken into account. Text-to-speech technology, for example, supplements text display on mobile or handheld devices to account for small screen size, screen glare, and other hardware or software constraints.

Performance – Performance requirements focus on minimizing user discomfort associated with reliability and robustness issues. A usability barrier is encountered, for example, when software or hardware recovery steps must be taken by older adult inexperienced in the use of computing and related technologies. Performance requirements may also be mandated by patient safety and security guidelines put forth by the U.S. Health Insurance Portability and Accountability Act of 1996.

Readability – Readability requirements take into account vision degradation due to normal aging as well as chronic illness and diseases. These requirements ensure that text, buttons, links, and other screen objects are readily visible to the older adult user.

Control – Control requirements take into account normal aging factors and chronic illnesses in the level of control provided to the end user. Control over technology can range from none (invasive) to full (noninvasive). For frail elderly, for example, invasive technologies (e.g., sensing devices) may provide home monitoring capabilities necessary to allow the person to age in place.

Intuitive - These requirements are based on existing user interface (UI) designs that have been traditionally used by older adults (e.g., radio buttons, television remotes). Existing UI designs minimize the learning curve associated with new UI designs. They also promote a high comfort level in using newly developed technologies because they have a familiar look and feel to them. This is especially important to older adults with minimal or no experience in using computing, Web, and communication technologies.

Security – Security requirements ensure personal information is not vulnerable to being stolen or unknowingly shared or sold.

Privacy – Privacy requirements ensure personally identifiable information remains under the control of the individual and is shared only with those who have access rights.

Adaptable – Adaptable requirements promote integration of emerging technologies with existing ones to promote widespread acceptance and use by the targeted user.

Utility Requirements

The utility requirements associated with assistive technologies take into account potential resistance by the targeted user. In particular, the life stage of an older adult may impact tolerance of certain technological designs perceived as complex and invasive with little value added to everyday living.

Manage Events or Activities –Automated support for managing daily events add value to everyday living. Automated medication reminders, for example, promote long-term health and wellness given that such support promotes consistent, correct, and complete adherence to medication management.

Fast Information Dissemination – Fast and transparent information dissemination (e.g., older adult has fallen in the home) promotes longevity of life and aging in place.

Promote Social Interaction - Automated support of social interaction minimizes older adult isolation primarily due to being homebound. Online journals, blogs, email and text messaging, and other interaction-based tools offer a means of remaining virtually connected thus eliminating physical and geographic boundaries.

Monitor Mental or Physical Health –Automated monitoring support for those with chronic and age-related diseases promotes early intervention with the potential for improved quality of life.

Support Cognitive Functions – Memory loss is a normal part of aging. Technologies that support memory recall add value in performing daily tasks. For those with memory loss due to chronic illnesses, memory aids may prolong a move to an institutionalized care setting.

Technology Requirements

The technology requirements component focuses on profiling hardware and software for home use of assistive technologies. Internet access may be required for assistive technologies that transmit data from the home to family or healthcare personnel. Home sensor devices may be connected to existing security systems for continuous monitoring of movement within the home. Other technologies may require personal computers with a particular version of an operating system to utilize software applications. Weight and size may play a role in whether a device is a viable one especially for mobile or handheld technologies.

3.2 Profiles

User Profile

The user profile encompasses personal characteristics that traditionally have been part of usability studies. These characteristics often include age, gender, education, and reading comprehension. They may also include computing experience, Web and mobile technology usage, and typing skills, among others. The user profile provides a means of assessing assistive technologies in terms of ease-of-use, learning curve, memory recall, and other usability factors.

Health Profile

The health profile encompasses characteristics that might impede the use of technology due to chronic illnesses or diseases and the resulting impacts on vision, cognition, motor skills, and hearing. For users suffering from Fibromyalgia, arthritis, or other neuromuscular diseases, for example, typing on a small device may be impossible when designs are not made accessible to those with lost sensitivity in fingertips or lost dexterity in fingers and hands.

Aging Profile

Vision, hearing, motor skills, and cognition are continuously affected by the normal aging process. These impairments can have a profound impact on the use of technology that hasn't been designed with the aging user in mind. Age-related diseases (e.g., cataracts) can compound impairments associated with normal aging. Technologies that are difficult to use by healthy older adults become virtually impossible to use by those with age-related diseases.

4. CONCLUSION AND FUTURE RESEARCH

Assistive technologies offer great potential in supporting daily living activities, improving quality of life, and enhancing social interaction by older adults who are homebound, isolated, disabled, or chronically ill. The need for such technologies will continue to grow with the impending explosion of the aging population and

Table 2. National goals associated with the development of assistive technologies for older adults

Develop creative products to support older adult independence. Research is needed to identify innovative technologies to promote aging in place given the high cost of institutionalized care. These include noninvasive technologies for which the older adult user maintains control over information gathered and disseminated.
Create public awareness of available technologies. A national infrastructure is needed for public awareness of innovative technologies to promote aging in place. This includes the effective dissemination of research outcomes that can be readily expanded into the realm of product development.
Design technology products that assist the broadest range of consumers. Additional research is needed in the area of universal access so that all technologies are made available to those with and without disabilities. The promotion of universal access, at both national and international levels, ensures the broadest range of users have access to technologies.
Assure innovative and competitive leadership of U.S. technology to meet rapidly-increasing global demand for aging-related products and services. With national support, research and innovation infrastructures could be utilized to promote universal access from an international perspective. This would be inclusive of older adults with and without disabilities regardless of geographic location.

its strain on health care personnel, facilities, and other resources. This critical need is being recognized at a national level, as shown by the outcomes of the White House Conference on Aging (2005). Table 2 expands upon several of the national goals.

It became apparent in our compilation of a usability framework that novel interface designs were needed if handheld devices were to be viable as assistive technologies for older adults. As such, research has been initiated on interface designs that focus on universal access by a diverse group of users. A few of the lessons learned are summarized below.

Multimodal Capabilities - The significance of multimodal support became apparent in PocketBuddy usability studies involving older adult subjects. A number of subjects relied on multimodal feedback to ensure a task was completed. Though the button changed color, the subject would listen for a supplemental sound as an indicator that a button had been successfully tapped.

Novel Interface Designs - The design team designed a novel keyboard, as shown in Figure 2, as a means of promoting successful data entry by older adult users. Unfortunately, it was still inaccessible by 14% of the older adult subjects in the usability study. These subjects found the use of the keyboard frustrating given they could not accurately tap on a key. The design team is exploring other novel interface designs to promote usability by all older adult subjects.

Transparent Data Transmission - The usability framework uncovered the need for transparent Internet connectivity for transmission of data gathered on PocketBuddy by an older adult user. In our research, adult caregivers who are seventy years plus comprise a large percentage of targeted users. Many have minimal computing skills and are often consumed with caregiving responsibilities. These caregivers would have little time to learn new technologies and even less time to deal with complex aspects of a user interface.

Future research will study the integration of the usability framework with design space research conducted by Maciuszek et al. (2005). The objective would be a common frame of reference, which maps specific aspects of older adult life to be supported via new or enhanced assistive technologies. The usability framework would provide the means to characterize a user, technology constraints, and usability goals. This would provide a foundation upon which technology could be assessed in terms of user requirements to support aging in place goals.

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ENDNOTES

1. Refer to Becker and Webbe (2006) for an overview of aging factors and use of assistive technology.
2. A Statistic for Alzheimer's disease (AD) as a chronic condition is not part of the Central for Disease (CDC) Control's report. Hence AD does not appear in Table 1. However, the CDC reports AD as a leading cause of death (3.2%) for those 65 years and older.
3. The keyboard shown on the right is part of a user interface design filed in a patent disclosure.

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