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LONG PAPER

The impact of aging on access to technology

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Abstract The number of people over the age of 65 is increasing worldwide with the fastest growing subgroup those aged 80+ years. Computer and information technologies hold promise in terms of increasing the quality of life for older people. However, successful use of technology by older adults is predicated on systems that are designed to accommodate the needs and preferences of this user group. This paper discusses the implications of age-related changes in cognition for system design. Generally, the existing literature shows that, although older adults are willing to use technology, many report usability problems with existing systems and these problems may in part be due to the cognitive and perceptual demands placed on the user. These findings are discussed in terms of guidelines for system design.

Keywords Older adults · Use of technology · System design

Introduction

Two major demographic trends underscore the importance of considering technology adoption by older adults: the aging of the population and rapid dissemination of technology within most societal contexts. In the past decade, developments in computer and information technologies have occurred at an unprecedented rate, and technology has become an integral component of work, education, healthcare, communication and entertainment. For example, in 2006, 73% of Americans reported that they used the Internet, and 42% have broadband connections at home [45]. Use of automatic teller machines, interactive telephone-based menu systems, cellular telephones, and VCRs is also quite common. Furthermore, telephones, television, home security systems, and other communication devices are becoming more integrated with computer network resources, providing faster and more powerful interactive services. There is also a trend toward integrating functions within smaller handheld devices (e.g., cell phones).

At the same time that we are witnessing explosive developments in technology, the population is aging. In 2003 people aged 65+ year, in the United States, numbered about 35 million and represented approximately 13% of the population. By 2030, this number is expected to increase to about 71 million, representing 20% of the population (Fig. 1). Moreover, there will be a dramatic increase in those aged 85+ years, from about 4 million in 2000 to nearly 21 million by 2050 [19]. Similar trends are occurring worldwide. By 2030, the percentage of people aged 65+ in Europe will be about 24%, and about 12% in Asia and Latin America [27].

Recent data for the USA also indicate that although the use of technology such as computers and the Internet among older adults is increasing, there is still an age-based digital divide (Fig. 2). In 2005 about 26% of people age 65+ were Internet users, as compared to 67% of people age 50–64 and 80% of those 30–49 years old [44]. Similar trends exist in the European Union (EU). In the EU, 48% of the households had access to

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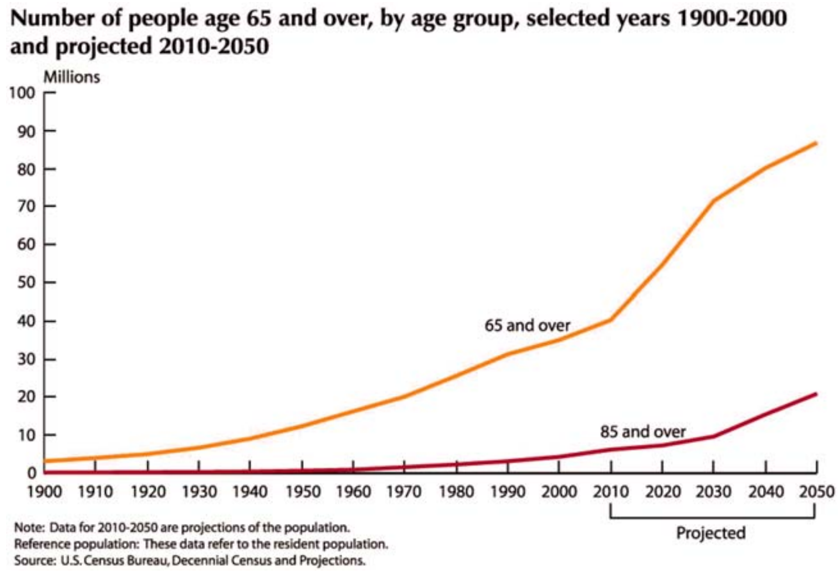

Fig. 1 Projected growth of the people aged 65+ in the United States. Data source: federal interagency forum on aging-related statistics, 2005

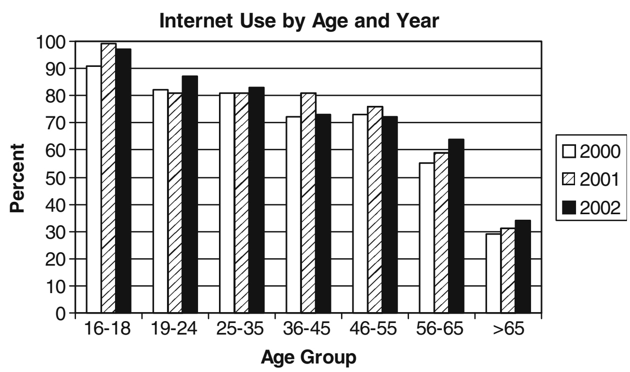

Fig. 2 Internet use among older adults in the United States. Data source: the UCLA internet report–''surveying the digital future'' UCLA center for communication policy, January 2003

the Internet in 2005, and 23% had a broadband connection. However, a gap still remains between users and non-users according to age. Specifically, the proportion of computer or Internet users among those 16–24 years of age is three times higher than among persons 55–74 [18]. Recent data also indicate that older adults use other forms of technology such as ATMs and VCRs less than younger adults [9].

Not having access to and being able to use technology may put older adults at a disadvantage in terms of their ability to live independently. For example, the Internet is rapidly becoming a major vehicle for communication and information dissemination about health, community and government services. Technology also offers the potential for enhancing the quality of life of older people by augmenting their ability to perform a variety of tasks and access information. For example, use of the Internet can help mitigate problems with social isolation and foster communication with family and friends. Use of the Internet can also facilitate the performance of activities such as banking and shopping and can enhance educational and employment opportunities for older adults. Technology may also allow older people to take a more active role in their own healthcare and enable those with some type of chronic condition to remain at home. However, as discussed by Dickinson and Gregor [15], currently there is little systematic evidence to support the notion that computers in and of themselves have a positive effect on the well-being of older adults. Many of the studies that have examined this issue have been plagued by methodological shortcomings. As such, there is a need for more rigorous research in this area. Additionally, as noted by Dickinson and Gregor [15], technology may also have some negative effects on well-being and that it is important to ensure that the introduction of technology into the lives of older people is done systematically and with caution.

To make technology useful to, and usable by, older adults, a challenge for the research and design community is to ''know thy user'' and better understand the needs, preferences and abilities of older people. It is fairly well established that many technology products and systems are not easily accessible to older people. There are of course a myriad of reasons for this, such as cost, lack of access to training programs, etc. However, to a large extent lack of accessibility is due to the fact that designers are unaware of the needs of users with varying abilities, or do not know how to accommodate their needs in the design process [26]. For example, recent findings from an observational study of designers involved in a design competition for older people

[21] found that the designers tended to restrict their use of user information and user involvement in the design process.

This paper will discuss the implications of age-related changes in abilities that have relevance to system design. The focus of the discussion is on cognitive processes. There are many other excellent sources of other age-related changes in abilities that have relevance to the design of technical systems (e.g. [3, 20]). Recommendations to accommodate these age-related changes in abilities will also be discussed. In addition, a brief discussion of strategies to include the needs of older people in the design process will be presented. Again, there are many excellent sources on design processes (e.g. [7, 35, 36]). It is hoped that this paper will highlight some important issues and in doing so will help bridge the existing age-related digital divide.

Are older adults willing to use technology?

A commonly held belief is that older people are unwilling to use technology such as computers. Despite this claim, the available data largely dispute this stereotype and indicate that older people are receptive to using technology. However, they often express more anxiety about their ability to use these systems and less confidence in their ability to use them successfully [9, 30]. Clearly, attitudes toward technology are important predictors of technology adoption, as are other factors such as available training and technical support, ease of access, cost, and the type of applications that are available.

For example, Rogers and colleagues [48] found that older adults were less likely to use automatic teller machines (ATMs) than younger adults. However, the majority of the older people in their sample indicated they would be willing to use ATMs if trained to do so.

In a study examining the use of e-mail among a sample of older women, it emerged that all participants found it valuable to have a computer in their home [10]. It was also found that the perceived usefulness of the system and system reliability were important factors with respect to usage. When the participants were asked what type of computer applications they would like, the most common requests included emergency response features, continuing education, health information, and banking/shopping. Selwyn and colleagues [52] examined data from a household survey on the use of information and communication technologies (ICT) from a sample of 352 individuals aged 60+ years in England and Wales. They found that use of computers and the Internet was relatively low and restricted to applications such as e-mail. Furthermore, the primary reason for non-adoption of computers was the lack of perceived utility of many applications and services. Similarly, a more recent study [17] found that older adults perceived the Internet as a potentially valuable source of health information and indicated that they would use the Internet to seek health-related information and advice. However, the participants also reported usability problems with health web sites, and, as expected, usability were related to search performance. Other studies have also indicated that, although older adults are receptive to using technology, they often have difficulty performing technology-based tasks. For example, Mead et al. [33] examined the ability of younger and older adults to use an online library database. Overall, the younger adults achieved more success than did the older adults in performing the searches. They also used more efficient search strategies. The older adults also made more errors when formulating search queries and had more difficulty recovering from these errors.

Kubeck et al. [28] investigated age differences in finding information using the Internet in a naturalistic setting. They found that older people tended to use less efficient search strategies than younger people and were also less likely to find ‘‘correct answers’’. However, they also found that, with training, older adults were successful in their searches and had very positive reactions to their ‘‘Internet experiences’’. In a recent study, Dickinson and colleagues [16] found that about 50% of a group of older adult novice computer users failed to complete basic e-mail tasks. The authors attributed many of the user difficulties to the complexity of the interface design.

Data also indicate that older adults are able to acquire the skills needed to use new technologies. However, training times are typically longer for older people, and they may require more practice and assistance during training [6]. For example, Dickinson and Gregor [15] completed a literature review examining the impact of computer use on the well-being of older adults. One of the findings of their study was that novices, especially those who are frail, need considerably more support when using computer technology. The authors note that most computer systems as currently configured demand considerable knowledge to set up and use and that to a large extent current computer systems are not usable for frail older people, unless they have considerable support.

Overall, the available data indicate that older people are not ‘‘technophobic’’ and are willing and able to use technology such as computers. However, the nature of their experience with technology, available support and the perceived usefulness of technology applications are important determinants of attitudes, confidence and comfort using technology and ultimately technology adoption. Furthermore, many forms of technology such as computers pose usability challenges for older adults.

Age-related changes in cognitive processes: implications for design

Overview of aging and cognition

There are a number of normative age-related number of changes in cognition that have implications for the design of computers and technical systems. Prior to discussing these changes, it is important to recognize that older adults as a group are very heterogeneous and individual differences are very prevalent throughout the life course. Aging is a highly individualized process and with increasing age there is an increase in inter-individual differences in rate, onset and direction of change in most functions and processes. This means that older people vary considerably in their abilities, skills and experiences [4]. Thus, one cannot draw conclusions on age-technology interaction on the basis of chronological age alone. Designers should instead use age as an index of potential physical and behavioral changes that occur with adulthood.

However, although there are wide individual differences in rate and onset of changes in cognition, increased age is generally associated with a decline in aspects of fluid intelligence, which is generally referred to as the processing and reasoning components of intelligence and related to aptitude for learning. In contrast, crystallized intelligence, which is generally defined as knowledge acquired through education and experience [25], tends to remain stable or increase throughout the lifespan until at least the later decades. A number of studies have shown that age is generally positive related to knowledge across a variety of domains (e.g. [1, 2]).

With respect to fluid intelligence, working memory which refers to the ability to keep information active while processing or using it, declines with age as does the ability to select or attend to cues/information in the environment (e.g., location of information on websites). Prospective memory or the ability to remember to do something in the future (e.g., take medications) also declines with age. Aging is also associated with declines in spatial cognition, which is the ability to manipulate images or patterns mentally or represent spatial relationships among objects or components. In addition, if an activity involves multi-tasking (doing two things at once) older adults tend to perform at lower levels than younger people, especially if the tasks are complex. Older people may also have difficulty comprehending language if inferences are required and connections between ideas are not explicit. Processing speed also declines with age, so that older people tend to take longer to process incoming information and typically require a longer time to respond (e.g. [42]). Age-related declines in these components of cognition are especially apparent under conditions of complexity or when a task represents an unfamiliar cognitive domain, such as is the case when confronting new technology. Generally, the skill acquisition literature indicates that older adults learn new skills more slowly than younger adults and may not reach the same levels of performance (e.g. [5, 47, 49]).

Potential implications of age-related changes in cognition to human/technology interactions

Age-related changes in cognition have important implications for the design of technical systems. Essentially, human-technology interaction is an information-processing task. In most cases, during an interaction with technology the user is required to search for and identify displayed information, select responses based on this information, recall commands and operating procedures associated with those responses and execute the response [46]. In fact, numerous studies (e.g. [12–14, 54]) have shown that cognitive abilities such as working memory, attention, and spatial abilities are important predictors of performance of technology-based tasks (Table 1).

For example, as shown in Table 1, the authors found that working memory was an important predictor of the ability to navigate interactive telephone menu systems to solve problems related to banking and electrical utility service. The obtained data also indicated that older adults had more difficulty using these menus than younger adults and found the use of these systems to be frustrating and difficult. An additional result is that cognitive abilities such as working memory and perceptual speed are important to the successful performance of computer-based information search and retrieval tasks. Pak and colleagues [41] found that psychomotor and perceptual speed and spatial visualization, which refers to the ability to manipulate or transform the image of spatial patterns into other arrangements, was a significant predictor a performance in a hypertext-based information search task when the navigational demands of the task were high. In that study, participants (aged 18–29 years)

Table 1 Cognitive abilities important to performance of technology-based tasks

Authors	Computer application	Cognitive abilities
Vincente, Hayes, and Williges [55]	Information search and retrieval	Visualization ability, verbal ability
Czaja, Hammond, Blascovich, and Swede [11]	Text-editing	Spatial memory and reasoning
Sein and Bostrom [51]	Electronic e-mail	Spatial ability
Seagull and Walker [50]	Information search and retrieval	Perceptual speed, visualization ability
Lohse [29]	Graphical aids	Working memory
Morrow, Leirer, Carver, and Tanke [34]	Health appointment attendance	Vocabulary, memory span, and processing speed
Czaja and Sharit [11]	Data entry	Psychomotor skills and visuo-spatial abilities
Czaja et al. [14]	Information search and retrieval	Processing speed, memory, attention
Sharit, Czaja, Nair, and Lee [54]	Interactive telephone voice menu systems	Working memory
Sharit, Czaja, Hernandez, Yang, Perdomo, Lewis, Lee and Nair [53]	Information search and retrieval/e-mail	Psychomotor speed, working memory, verbal abilities, attention
Pak, Rogers, and Fisk [41]	Computer-based information search	Psychomotor speed, perceptual speed, spatial orientation

searched for information related to eight topical domains. Task difficulty was manipulated by varying the number of steps required to retrieve the information. Navigational demands varied according to the navigational aid available, a map (high demand) or step-by-step instructions. The conclusion from this study was that, in addition to reducing the working memory demands of computer tasks, designers should also strive to less spatial orientation demands by reducing navigational requirements. These suggestions are especially important for older adults, as spatial abilities tend to decline with age.

Recent data also indicate that cognitive abilities are also related to technology adoption. For example, people with higher fluid intelligence are more likely to adopt new technologies such as computers and the Internet [8]. This is likely due to the fact that adoption of new technology requires new learning, which relies heavily on component cognitive abilities underlying fluid intelligence.

Ultimately, age-related changes in cognition may have a negative impact on access and use of technology by older adults. For example, declines in working memory may make it difficult for older people to learn new concepts or skills, recall complex operational procedures, or navigate complex menu structures. Declines in attention may make it difficult for older people to switch their attention between competing displays of information (e.g., split screens) or process multiple forms of information (e.g., text and speech) simultaneously. Older adults may also have problems attending to or selecting elements such as icons or keywords on complex displays, for instance overly crowded or poorly organized websites. Inconsistencies in operational procedures, functions or symbols may also make it difficult for older people to learn new applications or generalize across technologies. Declines in processing speed may also make it difficult for older people to comprehend quickly scrolling text or handle temporal constraints associated with pop-up menus or system queries (e.g., time limits on password or information requests).

Older adults are also more likely to make errors when interacting with technical systems and rely on help systems more for error recovery. Thus, the design features of on-line help systems, error messages and instructional manuals are particularly important for this user group. Poorly designed help information is likely to have the biggest impact on older users [20].

However, despite the fact that older people may have more difficulties than younger people using information technologies, the literature also clearly indicates that system design makes a difference. For example, a series of studies was conducted [12–14] examining age performance differences on a variety of simulated computer-based tasks (e.g., data entry, inventory management, customer service). Overall, the results of these studies indicate that older adults are willing and able to perform these types of tasks. However, generally the younger adults performed at higher levels than the older people. Importantly, the data also indicated that there was considerable variability in performance among the older people (60–75 years) and that with task experience those in their middle years (40–59 years) performed at roughly the same levels as the young adults (20–39 years). In fact, task experience resulted in performance improvements for people of all ages. The results also indicated that design changes resulted in performance improvements. For example, for the data entry task redesign of the data entry forms and data entry screens to highlight relevant information and enhance compatibility, and the provision of on screen aids to reduce demands on working memory, resulted in reduced error rates and faster performance for all participants. A recent study by Sharit and colleagues [54] found that the use of a graphical aid that provided a visual model of the menu system improved the ability of older people to navigate telephone menu systems (Fig. 3).

Investigators have also shown that training interventions can improve the performance of older adults on technology-based tasks. Mead and Fisk [32] in a study examining training for ATM machines, found age and training interactions such that there were greater gains for older adults for procedural (‘‘action’’) versus conceptual training. Unfortunately, there is limited data available on how to best train older adults for technology-based tasks. There are general guidelines regarding design of training programs for older adults [20] that include recommendations such as allowing extra time for training, ensuring that help is available and provide opportunities for the learner to be actively involved in the learning process. However, these guidelines do not indicate what type of training technique is best suited for a particular task, technology or application. In this regard, Mayhorn and colleagues [31] provide suggestions for the development of effective computer training for older adults. They stress the importance of applying a ‘‘systems approach’’ to the design of training programs where the goals, abilities, and experience levels of older adults are considered in the design and evaluation of instructional programs and materials.

How can we accommodate the needs and preferences of older adults in the system design process?

To ensure that computer and information systems are useful and beneficial to older people a human factors engineering or user centered approach to design is required [39]. Essentially, a user centered approach involves: (1) an early focus on users; (2) empirical measurement of users needs, requirements and performance; (3) iterative design and (4) participatory design [23, 38]. This amounts to incorporating user requirements, user goals and user tasks into the design process.

There are guidelines available which can be used as a starting point in the design process [20]. Table 2 provides a summary of guidelines for interface design related to age-related changes in cognition. Recently, the National Institute on Aging and National Library of Medicine also published guidelines for Web design for older adults. In addition, the World Wide Web Consortium provides guidelines for web pages and software for persons with disabilities (http://www.w3.org/TR/WAI-WEBCONTENT/). However, some guidelines (e.g., decrease demands on working memory) are somehow vague and difficult to implement. Also, as discussed by Hanson and Crayne [24], guidelines or standards do not guarantee a good experience for all users. For example, guidelines to help people with severe visual impairments, such as text-only software, may prove to be challenging for individuals with literacy problems. In this regard IBM is currently developing software, Web Adaptation Technology (see [24] for a more complete description of this project) that allows users to make adjustments to Web pages to tailor them to their own needs. Results from initial testing of the product with older adults indicate that user reactions to this product have been positive and that users have taken advantage of the available features. In addition, they have offered some useful suggestions for product improvement.

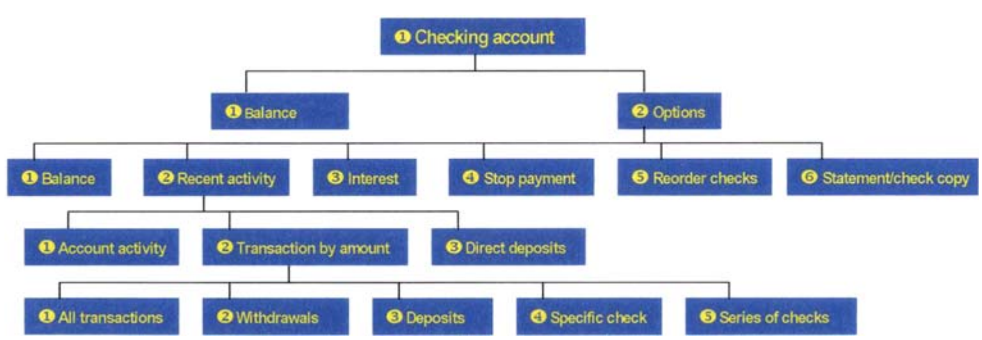

Fig. 3 Example of the graphical aid used to facilitate navigational through a telephone menu system

Table 2 Interface design guidelines for computer systems for older adults

Minimize visual clutter (e.g., too much information on a webpage) and irrelevant screen information
Present screen information in consistent locations (e.g., error messages) and where possible provide a standardized format across applications
Adhere to principles of perceptual organization (e.g., natural grouping of information)
Highlight important screen information and ensure that options that are most important or used most frequently are visible and easily located
Provide navigational tools such as a site map or a search history tool
Use icons that are easily discriminated and meaningful
Provide location information indicating where the user currently is within an application
Avoid technical jargon and the use of complex command languages
Minimize demands on working memory (e.g., minimize the need to recall complex operating procedures or provide aids)
Avoid automatically scrolling text
Provide feedback about actions such as task completion or text selection
Avoid complex command languages and use simple and familiar language
Minimize opportunities for error by providing action confirmation prompts (e.g., "are you sure you want to delete this text?")
Provide adaptability and system flexibility for different user levels
Ensure there is adequate time to respond to prompts and queries
Use operating procedures that are consistent within and across applications
Provide easy to use on-line aiding and support documentation

The work of Hanson and her colleagues underscores the importance of involving older people in the design and testing of systems and products. Although the existing literature and standards provide useful information and can aid designers, accommodating the needs of older adults and those with varying abilities requires user involvement in the design process. A number of approaches and methodologies have evolved to help ensure that all potential users are considered in the design process and there are numerous examples in the literature including Universal Design [40], Inclusive Design [7] and Ordinary and Extraordinary Design [37] that focus specifically on older adults and those with disabilities. Keates and Clarkson [26] have also developed a tool to measure the inclusivity of a design to help designers understand how many people are excluded by a particular design. In addition, several authors (e.g. [22]) provide general approaches for designing usable systems. While all of these approaches have associated strengths and weaknesses, they provide useful examples of how to achieve user-centered design.

Final comments

Information and computer technologies have become an integral component of everyday life. Unfortunately, an age-related digital divided still exists in the use of these technologies. Usability problems relate to screen design, input device design, complex commands and operating procedures, and inadequate training and instructional support often prevent older adults from successfully interacting with these systems. Data also suggest that certain technology applications may not be useful to older people.

As discussed in this paper, there are many age-related changes in cognitive abilities that have relevance to system design. There are also age-related changes in other processes such as vision and psycho-motor abilities that are equally important to design. However, to a large extent, designers do not consider older adults as active users of technology, and thus many interfaces are designed without consideration of age-related changes in abilities. Furthermore, many designers have limited understanding of the aging process, or of how to design systems to accommodate this user group.

To this end, there are guidelines and examples in the literature that can aid the design process. However, given that older adults are not a homogenous user group, guidelines are in and of themselves insufficient. It is critical to involve older people in the design and testing of technical systems and applications. As discussed in this paper, there are many references in the literature that provide examples of approaches to user centered design. There is also a need for more rigorous and systematic research in this area. Many studies that have been conducted involve small samples or lack of appropriate experimental control. Finally, in addition to design, there are a number of other issues regarding aging and technology that need to be addressed such as safety, privacy and quality of life.

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