Nuray Aykin (Ed.)

Internationalization, Design and Global Development

Third International Conference, IDGD 2009
Held as Part of HCI International 2009
San Diego, CA, USA, July 19-24, 2009
Proceedings

Springer

A Systematic Review of Technologies Designed to Improve and Assist Cognitive Decline for Both the Current and Future Aging Populations

Kelley Gurley and Anthony F. Norcio

Department of Information Systems
University of Maryland Baltimore County (UMBC)
Baltimore, MD 21250 USA
{kgurley1,norcio}@umbc.edu

Abstract. This paper serves as a literature review focused on understanding the technologies available for all aging populations. It also presents some limitations involved in providing alternative health care and discusses some considerations to designing technologies for future aging populations.

Keywords: Cognitive Decline, Aging Population, Assistive Technologies, Robotics, Telehealth.

1 Introduction

Information and communication technologies have become ubiquitous in today's everyday life [41]. A few years ago it was almost inconceivable that most of yesterday's human to human interactions would be replaced with the use of some form of human to computer interaction. Most of the generation x population i.e. people born between 1965 and 1980, use technology to assist in accomplishing tasks and to provide some form of communication and entertainment in their everyday use. According to future projections, many people from this future population would have attained higher levels of education than previous generations and would also have more computer skills than the previous generations. Trend projections explain that more than 32 million of older adults have a computer at home and 26% are internet users. This is in contrast to 62 million people between 35- 54 years old having a computer and 80% of people age 30 – 49 years old using the internet. This information demonstrates the shift of technology users and their comfort levels with devices, technology, gadgets etc. [12]. This may demonstrate an easier transition to depend on technology and limit some of the concerns with the adoption of technology that is faced by the current aging generation [31].

As we age, there are also many medical ailments that we may encounter, regardless of educational background or socioeconomic status. Some of these include chronic diseases like heart conditions, diabetes mellitus, arthritis, neurological conditions, cognitive impairment, along with decreased hearing and vision [32]. Special accommodations of equipment or software due to age-associated cognitive or perceptual changes may also be required for all aging populations [22, 24].

N. Aykin (Ed.): Internationalization, Design, LNCS 5623, pp. 156–163, 2009.

It is important to indicate that this review is focused on technologies designed to support normal decline associated with aging and not decline from Alzheimer's disease. This is an incurable progressive and fatal brain disease [2] and requires medical investigations, treatments and intervention. We will review what the current literature suggest about the familiarity to technology and how it can assist, prevent, slow down or reverse cognitive decline [37, 45]. Though the current literature provides methodologies to produce efficient technologies and interfaces for the current aging population [11,15,40,46], there is still a gap in providing solutions for a population that will be much more advanced, more technologically savvy and much more knowledgeable in what they consider to be good end products and good usable design [7, 47]. There are also many studies that discuss the aging adult and cognitive decline on the current population [4, 41, 44], but no significant literature that focuses on the future aging population who has been projected to have a higher standard of expectations for how things should be done and who will aggressively seek a well designed product [10, 12, 43].

2 Background

Currently, there are less than 10% of aged individuals in the society. Predictions have been made that by the year 2050; more than 20% of the population will be older than 80 years of age [35]. As the aging population becomes a more significant part of the overall US population, it is important to consider how one could retain current cognitive vitality. Cognitive decline, memory loss, decline in processing speed and the slowing of basic cognitive process to some degree are almost expected in normal aging and are frequently studied [42]. There are several research studies that have documented the effects of either training interventions that involve some type of memory training or discuss how the older adult depends on environmental support for memory retrieval operations [4, 5, 37, 48]. There is also documentation that shows significant improvement in cognition when participating in different types of physical activities and exercise, (riding a bicycle, reading, climbing stairs etc) by finding patterns which can show significant ways for improving cognitive decline to some degree [9]. Good user design also considers cognitive load, memory and spatial design factors for their end user [10, 48].

3 Technologies

Technologies have been able to provide medical assistance for many years. From, Wilhelm Conrad Röntgen in 1895 [29], who discovered the medical use of x-rays, to the recent home health device by Intel that supports telemedicine, humans have been using technology to assist with medical diagnosis, treatments and support for many years. Though, many diseases have been eradicated through the forecasting and diagnostic use of technology [36] and many health conditions, impairments and disabilities alleviated through the supportive use of technology, decline in cognitive performance is still a major threat and a review of some existing technologies is necessary.

3.1 Tele-health

Tele-health involves the communication of images, voice, and data between two or more sites using telecommunications [39]. This provides health services such as clinical advice, consultation, education, and training services [23]. This form of telemedicine has been used in many countries for the delivery of mental health care, particularly psychiatric services, but there is not much documented data that demonstrates the effectiveness of this approach to this form of health services delivery. A big advancement in this field is the new monitoring device by Intel [17]. This device captures patient vital signs (blood pressure, weight, blood glucose etc) and sends this electronically to the primary care provider who can contact the patient direct through the video conferencing functionality.

Another form of telemedicine is robotic surgery. This involves the surgeon and a robot to work in a master-slave capacity while performing some form of surgery. However, at present they have only been approved for limited clinical use [3]. A main barrier to the development of these types of systems is the rigorous licensure requirements and the difficult process to get "buy in" from each state for a physician to practice telemedicine [28]. A common barrier to physicians is the non-existent reimbursement process for providing telemedicine. The high cost of telecommunications has also affected the growth of this aspect of health care.

3.2 Adaptive Technologies

Adaptive technologies refer to technologies, devices etc. that can adapt to the current user [30]. This will be important for adults that develop disabilities or limitations in using particular devices and generally for the older adult who responds more slowly to simple stimuli and take longer to learn new material [14]. An example of an adaptive technology which can be worn by the user would be a pair of eyeglasses that can enhance the peripheral field of vision of the user [18]. Another type called a microelectromechanical system, can be placed in regular objects, an example would be a sensor, which can be placed into a cane (used by the blind or people with low vision) that provides information about nearby structures [16]. A third type is one that a user will normal interact with like the display on the dashboard while driving [14].

3.3 Assistive Technologies

Assistive technologies can assist a user with specific deficits in their abilities; find an alternative way of performing a task, an action or an activity [22]. These have been studied in detail for the rehabilitation treatment of cognitive disorders along with compensation for specific impairment and assessing the user's cognitive status [1]. These assistive technologies comprise of three main forms: Assurance, Compensation and Assessment systems [35].

Assurance Systems assist in ensuring safety and well-being. Sensors are a type of assurance system that can convert a physical signal into an electrical signal that may be manipulated symbolically on a computer. These can also be placed around a home to depict whether a stove top has been forgotten on and turn it off, etc or contact the caregiver [13, 21]. Transmittal of information to caregivers in real time is also helpful [33]. This can help monitor activities and help reduce the man power that is required

to manage home health care. It also assists with the aging in place initiatives which can be used to help an older adult live independently for longer periods [19, 26]. Interfaces that can be personalized by the user are currently being researched as cognitive decline occurs gradually in most cases. One example is that of a person forgetting to take their medications and the system tracking this continued pattern and initiate reminders through the television between the commercials or use of other familiar technology like a verbal reminder over the telephone [13].

However, these systems may give them a false sense of security as care-giver notification can be sent automatically and if malfunctions occur with failed delivery or receipt, alternative plans of action may not have been considered. For example, if a patient or elderly person falls, technologies exist that can notify emergency services. Also, if vital signs go below a specific threshold a notification can be sent to a caregiver to assist this person. However, if the caregiver does not respond at what point will emergency services be contacted? Additional questions that may be raised regarding this scenario may include: After how much time will an action occur? Can the user override the decision made by the system? Who will be responsible if the situation is not resolved in a timely manner? There are many more legal and ethical questions that could be raised and should be considered before full adoption and reliance of such systems.

Compensation systems help guide the user to complete daily activities. When a system monitors a user and determines that assistance is needed to help complete a task, a second set of systems is designed to help compensate for the cognitive impairment that the individual has encountered. They also encompass navigational support systems that help older adults navigate around their environment.

Assessment systems gather information to provide some sort of evaluation to determine how a person is doing. It can help monitor their cognitive functioning and work with other assistive technologies and adaptive technologies to assist the user in accomplishing a task. These are frequently studied and can encompass recording of vital signs, detecting user location etc. There are many benefits to such systems in independent care living and retirement communities as it can be informative to the caregiver and also help detect a user at risk for a fall or other events. Robots and other forms of artificial intelligence can also assist older adults, as memory deficits can lead to forgetting tasks; for example forgetting to take medications. A Personalized Robotic Assistant can remind the user that it is time to take the medications [35]. It can track whether an individual who has cognitive decline and incontinence has used the bathroom in the last 30 minutes and offer reminders when necessary. This also facilitates the idea of older persons managing their own health care and being able to better communicate with their health care providers [25].

4 Cognitive Orthotics

Cognitive orthotics or cognitive prosthetics are another form of assistance that are frequently studied and was developed for specific types of cognitive decline due to some type of trauma, disability, impairment or decline. Similar to how a prosthetic limb can help the user perform regular activities that would be difficult and sometimes impossible to perform, so can computer-based assistive technology work to

benefit the user with the special need, in this case an aging adult with some form of cognitive decline [8, 34]. It has been discussed that frequent cognitive training may reverse cognitive decline but there are still many questions that surround this reversal [42]. However, reversal has been successfully documented in several experiments that demonstrate the ability of cognitive training with the use of technology. A specific case was one of a medical doctor who began to show signs of significant memory deficits to a point where he was unable to remember any new information after 30 minutes. After using a scheduler system to help initiate an action, over a period of 6 months, he began to show improvement in his functional memory [8].

5 Technology Abandonment

It has been reported, that approximately one third of all assistive technologies are abandoned within one year of use especially within the first three months. Abandonment rates are from 8% for life-support devices to 75% for hearing aids depending on the device [38]. This failure of adoption rate can be explained in terms of the user, the environment surrounding the user and the device [19]. Many devices are designed to match a user with a specific need instead of matching the user to a device that will meet their needs. Sometimes the designers of these devices do not always know all of the situations surrounding the use of the device or the user's real needs. The constraints of time and money have led to many devices being tested on persons for whom they were not designed [6] which has lead to devices that do not meet the user's specific needs. Many devices are designed without proper considerations of human factors during the design of the device which can lead to an un-usable or inefficient device. In attempting to develop devices that are useful and usable, the designers and developers must involve the users of the products and when necessary their caregivers to encourage sustainability of the end product [20].

6 Conclusion

There are many limitations that are faced by the aging population today. These vary from their comfort levels of learning new technology, to using devices or interfaces that do not consider the older user in its design process. These can make it difficult to use and therefore difficult to adopt on a daily basis [27, 49]. There is also a need to research technologies that not only focus on assisting mild cognitive decline but also focus its reduction or reversal. Most of the literature focuses on physical impairments and cognitive decline of the aging population and explains how technology is being used to assist them. However, there is much needed information on how the current population will age and interact with existing and new technologies. This leads us to several theoretical questions about this future aging population and the use of technology. Would the "future aging population" really use technology more readily and more efficiently than the current older population? How do we test for this prediction as most of the technology that will be used has not yet been invented? Do we hypothesize on the current use of technology in specific cohorts and use this information to predict future patterns? How do we test accuracy on these predictions? What type

of methodology may be used to test these theories? There is significant ground work that needs to be completed and focus should be given to facilitating initiatives that involve studying this paradigm and developing methodologies towards the human-computer interaction for the future aging adult.

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