Designing Technology to Aid Cognition

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ABSTRACT
We present a framework for technological aids for cognition intended primarily for individuals with cognitive impairments and seniors experiencing cognitive decline. We illustrate the framework with concrete research projects and near-term challenges.

Categories and Subject Descriptors
K.4.2. [**Computer and society**]: Social issues – *assistive technologies for people with disabilities.*

General Terms: Design, experimentation, human factors.

Keywords: Technology for cognition, memory aids, cognitive decline, Alzheimer's disease, multimedia, collaboration technology, mobile devices, participatory design, user-centred design.

1. INTRODUCTION
Global advances in medicine, health, and nutrition are leading to a dramatically aging society. A 2001 U.N. report noted that 10% of the world's population today is over 60, and projected that this will increase to 20% by 2050, and 33% by 2150.

As we age, we typically experience cognitive decline. In many cases, disease results in even more serious and debilitating cognitive impairment. Degenerative disorders, which include cortical dementias such as Alzheimer's disease (AD) and subcortical dementias such as Parkinson's disease, are most prevalent.

According to the Canadian Institutes of Health Research, more than a quarter of million (280,000) Canadians had AD in 2006. By 2031, more than 750,000 Canadians are projected to have AD or a related dementia[1]. At the moment, caring for Canadians with AD costs about $5.5B each year.

Cognitive impairments also result from other less prevalent conditions — traumatic brain injuries (TBIs); vascular disorders such as strokes; other progressive disorders of the central nervous system such as multiple sclerosis (MS); toxic conditions such as alcoholism; infectious processes such as HIV and AIDS; brain tumors; oxygen deprivation; and metabolic conditions such as diabetes.

Cognitive decline also occurs routinely in individuals who are aging "normally." For example, a key aspect of normal cognition often taken for granted is memory. Memory is essential for participating in life and in work, for engaging in social interaction, and for preserving health. We need to make appointments and meet deadlines, take medications and see doctors. We must remember names and be able to associate them with faces, and respond intelligently in a conversation based on what has just been said and what has occurred in the recent past. We cannot constantly misplace our keys and wallets and glasses. Our lives are enriched by our memories of our past and by stories of the lives of our parents and grandparents.

We are most aware of the importance of memory when we forget something. We all have memory lapses; even those with normal memory struggle to remember names, appointments, facts, numbers, and details of procedures. Although a temporary loss of memory may be inconvenient for individuals with normal abilities, consistent memory loss can disrupt daily activities and cause medical setbacks, distress, social isolation, or unemployment.

The last twenty years has seen much research on technology for individuals with special needs [10]. Three examples are technology for visual impairments (e.g., reading machines, screen magnifiers, mobility aids), for speech and hearing impairments (e.g., hearing aids, closed-captioning systems, voice recognition and synthesis), and for motor disabilities (e.g., computer-based systems that enable quadriplegics to communicate through simple motions of individual body parts). The nine previous ASSETS conferences on Computers and Accessibility have played a major role in encouraging the publication of such work and the sharing of knowledge among researchers and students.

Although the field has focused on visual, speech, hearing, amd motor impairments, there has also been work on technology for individuals with cognitive impairments. Lamming [8] is a visionary early paper on electronic memory aids. A survey of Assistive Technology for Cognition (ATC) [9] concludes (p. 5): "ATC interventions can increase the efficiency of traditional rehabilitation practices by enhancing a person's ability to engage in therapeutic tasks independently and by broadening the range of contexts in which these tasks can be exercised..." A review [7] of external memory aids and computer-based procedures to enhance memory functioning in neurological patients, especially adults with non-progressive brain injury and individuals with mild to moderate memory deficits, presents evidence on the efficacy of external memory aids in clinical settings.

[1] U.S. numbers are over 10 times greater than Canadian. Worldwide incidence is projected to grow from the current 18 million to 34 million by 2025. More generally, the incidence of dementia worldwide may grow to 42 million by 2020 (the Lancet, December 2006).

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Special inspiration comes from achievements over 20 years by Dr. Elliot Cole and associates at the Institute for Cognitive Prosthetics [5]. They demonstrated with over one hundred patients that desktop computer technology can significantly help individuals with cognitive disabilities resulting from TBI and stroke. They conducted research on individuals with multiple cognitive deficits (including memory, executive dysfunction, language impairments, and social interaction problems) spanning a wide range of impairment, from mild to severe. In addition to designing for the individual with the brain injury, they developed techniques for incorporating needs of families, caregivers, and clinicians. Cole's results are encouraging, but he worked with cognitive deficits that have an acute onset and are non-progressive. AD is progressive dementia, and presents even greater challenges.

We have therefore begun a broad research program[2]:

- to design, develop, and evaluate prototype technology to aid human cognition
- to demonstrate health benefits that such technology afford to those with cognitive impairments
- to pursue more speculative and ambitious goals for such technology, viewing them not just as *prosthetic* or *compensatory* devices, but also as *rehabilitative* or *restorative* devices to enhance cognition, and even as *preventative* or *treatment* devices able to slow the rate at which cognitive impairments develop.

We situate projects within a novel seven-dimensional research framework [1,2] with the following dimensions:

- the impaired cognitive process: memory, e.g., reminding, orienting, reminiscing, finding, and recognizing; executive functions; or higher-level skills such as communicating
- the disease category, for example, MCI, AD, or amnesia, or even a population of those "normally aging"
- the goal, i.e., diagnostic[3], prosthetic, restorative, preventative, or some combination thereof
- the primary "users," i.e., the person with the cognitive disorder, the caregiver, the family, the clinician, or some combination of stakeholders
- the independence of the user, i.e., whether the individual with the cognitive disorder is to use the prosthesis unaided or with help
- the design approach, e.g., user-centered design, participatory design, or patient-centred design
- the technology employed in the cognitive aid, e.g., laptop computers, DVDs, personal digital assistants, cell phones, or configurations of tiny "ubiquitous computing" devices.

My keynote will review projects [3] illustrating such research[4]. These will include, from my laboratory, participatory design for and with individuals with amnesia [11], creating multimedia biographies for individuals with AD and their families [4], and two new projects — assisting individuals with the recall of names, and the development of a website to encourage brain fitness and to support research on brain fitness interventions.

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[2] This research is complementary to outstanding work led by Prof. Alex Mihailidis of the Department of Occupational Science and Therapy at U of T and Toronto Rehabilitation Institute (see http://www.torontorehab.on.ca/research/mihailidis.htm). Alex focuses primarily on cognitive aids for assisting physical tasks, e.g., hand washing, not falling down stairs, and moving in a smart wheelchair. I focus primarily on aids for cognition itself, e.g., remembering, communicating, making decisions, and problem solving.

[3] See, for example, a recent review [6] of research projects that propose novel methods for AD diagnosis.

[4] For a current enumeration of relevant projects and publications, see http://kmdi.utoronto.ca/rmb/.