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# Technologies for Aging Gracefully: A Systematic Design Space

**Ronald M. Baecker**

Technologies for Aging Gracefully  
Lab (TAGlab)  
Knowledge Media Design Institute  
and Dept. of Computer Science  
University of Toronto  
40 St. George St., Bahen 7228  
Toronto, ON M5S2E4 Canada  
rmb@kmdi.toronto.edu

**Abstract**

We present a design taxonomy of technology for senior citizens, use it to review systematically examples from the research literature and from our laboratory, and suggest how this framework can support imaginative and creative design variations.

**Keywords**

Senior citizens, aging, cognitive prostheses, mobile devices, multimedia, Alzheimer's disease, stroke.

**ACM Classification Keywords**

H.5.2. User interfaces; J.3. Life and medical sciences;  
K.4.2. Social issues.

**Introduction**

A 2001 U.N. report noted that 10% of the world's population was then over 60, and projected that this would increase to 20% by 2050, and 33% by 2150. Senior citizens have long used prosthetics for mobility such as crutches, for vision such as glasses, and for hearing such as hearing aids. Seniors are now also rapidly adopting information technology; for example, the largest increase in internet use since 2005 has been in the 70-75 year-old age group [6]. This suggests that there are interesting design opportunities for information technology to support graceful aging.

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## A Design Framework

Design frameworks help researchers and clinicians to understand, compare, and contrast approaches. Ideally, they also suggest novel solutions. The following design space extends previous work [1] with the following six dimensions:

1. What cognitive or social *process* is supported? E.g., memory skills dealing with reminding, orienting, reminiscing, finding, and recognizing; executive functions; or higher-level skills such as communicating and remaining connected with family and friends.
2. For what *population* is one designing? E.g., individuals with amnesia, mild cognitive impairment (MCI), Alzheimer's disease (AD), or stroke survivors, or a population of those "normally aging".
3. What is the *goal*? E.g., *diagnostic*; or *prosthetic*, i.e., compensating for an impaired function; or *rehabilitative*, i.e., restoring some function that is impaired; or *preventative*, e.g., slowing cognitive decline.
4. Who are the *users* and what is the *usage* pattern? E.g, the person with some impairment, caregiver, family, clinician, or some combination of stakeholders? Will the technology be used unaided or with assistance?
5. What *design approach* is used? E.g., *user-centered design* (UCD) — designing *for* users, *participatory design* (PD) — designing *with* users, or *patient-centred design* — design by a clinician for a specific patient.
6. What *technology* is employed? E.g., laptop computers, DVDs, smart cell phones, configurations of tiny "ubiquitous computing" devices, or neural implants. Also, is the technology fixed, or adaptive, or adaptable?

## Pioneering Research Projects

For over two decades starting in the mid 80s, Dr. Elliot Cole and associates [3] demonstrated with over one hundred patients that desktop computer technology can significantly and substantially aid individuals with cognitive deficits that result from conditions such as TBI and stroke. Identifying and exploiting what Cole terms "islands of abilities" allows the achievement of specific neurorehabilitation goals.

With the Memory Link program [11] beginning in the late 1980s, Dr. Brian Richards and colleagues applied errorless learning to teach persons with anterograde amnesia to use looseleaf "memory books" with alarm mechanisms to remind them of appointments and medications. Recently, smart phones have been introduced, also for communication and collaboration among amnesics and family members [13].

NeuroPage is a lightweight portable pager that also serves a reminding system. A study [12] of 143 brain-damaged patients' use of NeuroPage showed that more than 80% of patients completing the 16-week trial were significantly more successful with everyday activities such as self-care, taking medication, and keeping appointments. In most cases, improvement was maintained 7 weeks after returning the pager.

The ravages of chronic conditions such as AD, Parkinson's, and stroke are very often also devastating for caregivers. Dr. Elsa Marziali's elegant Caring for Others system [7] uses desktop videoconferencing to provide remote support by social service workers and social connections for 7/24 homebound caregivers of individuals with such conditions.

### **Current Projects in Our Lab**

Elsa and I have developed an effective production process [9] for creating multimedia biographies (digital life histories of entire lifespans) for persons with mid- or early-stage AD or MCI. The biographies stimulate memories, usually bring joy to the AD individual, enable family members to better remember their loved ones as they were before the AD, facilitate family conversation, and are useful for third-party caregivers [4].

Researchers and clinicians at Microsoft Research Cambridge [2] recently reported on the successful use of a novel automatic camera called SenseCam to enable recall of current episodes in the lives of individuals with amnesia or AD. We are carrying out a study comparing raw SenseCam footage to authored narrated slide shows incorporating selected SenseCam stills to memory stimulation with probing questions.

Context-aware cell phones can deliver valuable information for individuals with cognitive deficits. Building on a pilot exploration in which a smart phone suggests who one might encounter in a particular location [5], we are now generalizing this concept to the prediction of words and sentences to support communication by individuals with anomic aphasia.

We are also designing senior citizen gaming web sites for cognitive and social stimulation. One goal is to provide compelling environments that if used regularly might increase cognitive reserve [10] and thus one's resistance to mental aging and to the expression of AD. Another goal is to provide an environment for carrying out randomized controlled trials on the effectiveness of various mental fitness regimens [8].

### **Design Variations**

The six dimensions of each of the eight projects are summarized in Table 1. The design framework should also be a thinking tool suggesting new technologies and new uses for technology. Here are some examples:

*Population:* As users of a smart phone vary in the degree of cognitive impairment from MCI to mild AD to moderate AD, the inference engine should become progressively more directive and less reliant upon user control of what is displayed.

*Goal:* As goals for a gaming environment vary from prosthetic to rehabilitative to preventative, the games supported may have to be significantly different.

*Users:* Digital life histories may vary in production process, content, and usage depending upon the user(s): individuals, couples, small families, or large families dispersed throughout the world.

*Technology:* Display of names from a social network to aid name recall or of SenseCam images to aid recall of experiences may be done in significantly different ways on a smart phone, a laptop, a desktop or ambient tabletop display, and a wall display.

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	<i>Insitute for Cognitive Prosthetics [3]</i>	<i>Memory Link [11]</i>	<i>NeuroPage [12]</i>	<i>Caring for Others [7]</i>	<i>Multimedia Bios [4,9]</i>	<i>SenseCam Research [2]</i>	<i>Context-aware Cell Phones [5]</i>	<i>Online Gaming Environments [8]</i>
<i>Cognitive / social process</i>	Communications, organization, ... other skills	Reminding re medications & appointments	Reminding re medications & appointments	Social support	Reminiscing	Recall of recent experiences	Recall of words, sentences, and names	Cognitive and social stimulation
<i>Participant population</i>	Primarily individuals with TBI, stroke	Amnesic individuals	Brain-damaged patients	Homebound caregivers	Mid- or early-stage AD or MCI	Mid- or early-stage AD or MCI	People with anomic aphasia	Normally aging seniors
<i>Goal</i>	Rehabilitative	Prosthetic	Prosthetic + rehab.	Prosthetic	Prosthetic + rehab.	Prosthetic + rehab.	Prosthetic + rehab.	Preventative
<i>Users, usage</i>	Individuals	Individuals	Individuals, family "programming"	Individuals	Individuals + families	Individuals + families	Individuals	Individuals + families
<i>Design method</i>	Patient-centred design	UCD (user-centred design)	Not known	UCD	Participatory design + UCD	Participatory design + UCD	Patient-centred design + UCD	UCD
<i>Technology</i>	Desktop PCs+ telerehabilitation	Currently, smart phones	Electronic pagers	Desktop video conferencing	Multimedia on DVDs	Multimedia on PCs	Smart phones	Online games