Gerontechnology is an interdisciplinary field of research and application involving gerontology, the scientific study of aging, and technology, the development and distribution of technologically based products, environments, and services. One goal of gerontechnology is to use technology to prevent, delay, or compensate for the perceptual, cognitive, and physical declines of aging. A second is to use technology to support or enhance the opportunities associated with aging related to communication, leisure, learning, service, and artistic expression. Areas of application include housing, personal mobility and transportation, communication, health, work, and recreation and self-fulfilment. The methods used to determine older persons’ needs and preferences for technology are discussed, as is the central role of the user in the development, dispersal, and evaluation of technology. A clinical evaluation of the value of assistive technology is summarized. The educational activities and professional organizations that support the development of gerontechnology are described, and the article concludes with a discussion of financing and advocacy of this new discipline.

This article is based in part on an invited lecture by James L. Fozard, September 17, 1999, at the Center for Aging Studies at the University of South Florida, Tampa, Florida.

Address correspondence to James L. Fozard, Florida Geriatric Research Program, Morton Plant Mease Health Care, 207 Jeffords Street, Clearwater, FL 33756, USA. E-mail: James.Fozard@Baycare.org
*Gerontechnology* means engineering and technology for the benefit of aging and aged people. The word is a combination of *gerontology*, the scientific study of aging, and *technology*, the development and distribution of technological products, environments, and services. The term, coined by Graafmans and Brouwers (1989), is a blending of the sciences that comprise engineering and gerontology, both of which are multidisciplinary fields.

Our life experiences now and into the 21st century are occurring in the context of a worldwide change in the distribution of human ages that has never before happened in recorded history. At the same time, the environment in which people age is changing more rapidly than ever before. The natural and manmade environments provide both challenges and opportunities for aging. Challenges include age-associated declines in sensory, cognitive and physical functioning, mobility and greater vulnerability to disease. These losses are addressed either by engineering changes that compensate for, prevent or delay them. Prevention can take place at the tertiary, secondary, or primary level; the time frame for primary prevention may represent periods covering most of the human life span. Opportunities include the potential for new social relationships, second careers, further learning, volunteer, and social work, leisure activities, artistic endeavors and self-expression. These opportunities are addressed by enhancing technical application for daily living, communication, transportation, safe workplaces, learning and artistic endeavors.

**NEEDS AND INTERESTS OF OLDER PERSONS**

The special needs and interests of older persons with respect to technology include six areas: (a) housing; (b) communication; (c) personal mobility and transportation; (d) health; (e) work; and (f) recreation and self-fulfillment (Vercruyssen, Graafmans, Fozard, Bouma, & Rietsema 1997).

**Housing**

Aging in place is one of the highest priorities of aging people. It is not easy to alter living spaces to accommodate the changing needs of aging people who have traversed the life course from newlyweds to parents to empty-nesters. Adapting doorways, bathing facilities, stairs, and so forth to accommodate limitations in physical func-
tioning may be difficult. Building technology, architectural knowledge, and smart technology for controlling heating, lighting, and other environmental factors are sufficient to address these barriers in new construction (prevention and enhancement), but retrofitting (compensation) existing housing is far more difficult and expensive. Moreover, significant individual differences exist in preferences for modifying existing living spaces versus changing living environments (Slangen-deKort, Midden, & Wagenberg, 1998).

Communication
Meeting seniors' needs for social interaction, health, and safety are among the most important uses of communication technology, which now extends beyond the telephone to include fax, e-mail, digital photographs, remote control and monitoring devices, teleservices, multimedia, and computer-based communication devices (Meyer et al., 1999). The goals of prevention, compensation, and enhancement are all served by communication technology. Improvements in the ergonomics and user friendliness of the technological products being developed are needed to increase the use of many of these devices by older persons. Current work related to ergonomics in communication devices may be the first area in which so-called "smart" technology is used to make control devices more user friendly for older persons (Bouma, 2000).

Personal Mobility and Transportation
Most products and environments for personal mobility are compensatory (e.g., handrails, canes, walkers, wheelchairs, barrier-free environments). Technologies to prevent or delay physical limitations in personal mobility currently are being developed (Evans, 1995; Fozard, Metter, Brant, Pearson, & Baker, 1992; Rantanen et al., 1998). Age-related limitations in walking and other physical activities can be ameliorated by strength reserves developed and maintained by earlier strength training. Evidence linking strength differences in middle age to physical functioning some 25 years later has been reported (Rantanen et al., 1999). This information, along with the results of other studies (see Fozard & Heikkinen, 1998, for a review), provides for the first time baseline information from which long-term criteria for strength training may be established and evaluated.

Most current technological developments in transportation regarding aging focus on compensation for limitations is visual, cognitive, and physical functioning related to driving. In particular, surveys of
older drivers have indicated the importance of visual problems related to poor illumination and contrast, low conspicuousness, veiling glare, and difficulty in judging vehicle speed (Kline et al., 1992).

Health
Many health problems of older persons can be prevented or postponed by long-term nonmedical interventions, including nutrition, exercise, and reduction of chronic exposure to environmental pollutants (e.g., noise, chemicals, and adverse lifestyle choices regarding recreational drugs). Relevant applications of technology include long-term monitoring of physical and psychological activity of people in everyday situations (e.g., Bouten, Dauren, Verduin, & Janssen, 1997) to maintain optimal levels of functioning to prevent the subtle declines in physiological functioning often associated with aging.

Work
Age-associated losses in strength and health may pose significant challenges to the performance of middle-aged workers, particularly those in physically demanding jobs, even when the workers have performed successfully for many years (Ilmarinin & Louhevaara, 1994). Job redesign, alternative work, and compensatory physical conditioning are among the options available to provide safe working environments for aging workers who continue to perform physically demanding jobs.

As for second careers, work at home, and part-time jobs, an increasing number of jobs require computer-related skills. Work by Czaja and colleagues (Czaja, 1999) has indicated that longer periods of training are necessary for older workers to acquire such skills and that the perceptual motor speed of newly trained older workers will not equal that of younger ones.

Recreation and Self-Fulfillment
The number of computer games and programs for creating visual art and music is continually increasing. There is a substantial interest in education, including distance learning, on the part of older persons. Determining the interests and desires of older users has received little attention in a market targeted largely toward children and young adults. This is a rich area for development.
THE LINK BETWEEN GERONTECHNOLOGY AND AGING

In addition to their direct influence on aging, environmental factors influence the phenotypic expression of genetic determinants of aging because of lifelong differences in exposure to environmental toxins, disease, accidents, nutrition, recreational drugs, recreational activities and variations in the manmade environment. Engineering the environment has enormous potential to substantially influence the course of human aging. To understand the natural history of aging the natural history of a changing environment must be considered. The significance of an attained age and the biological and social processes leading to it can only be understood by relating the two.

Theories that relate aging to the environment are referred to as transactional (Fozard & Popkin, 1978; Lawton & Nahemow, 1973). The central theoretical idea of human factors engineering and ergonomics is transactional. Man and machine should be studied as a functional unit or system. Optimal system output can be achieved by changing man, the environment, or both. Lawton (1998), who identified tensions or imbalances between the environment and human needs in terms of structural changes, described the temporal aspect of person–environment interactions. At any point in time, the world of technical products and services may interfere with or enhance the activities of people.

DETERMINING USER NEEDS AND TECHNOLOGY PREFERENCES

Gerontechnology requires information on the distribution of activities of older persons. There have been a variety of approaches to acquiring this information, some of which are described in the sections that follow.

User Participation in Design Process

A fundamental premise of gerontechnology is that the development and distribution of technological products should involve the user in all phases of the development of a product, from needs assessment through input to evaluation of the product prototype itself (Coleman, 1998). Designers often aspire to universal design or design for all. The central idea is that a product that is ergonomically suitable for persons who are physically or perceptually challenged will be usable
and useful for all others. This approach is attractive because it minimizes the stigma often associated with products obviously designed for persons with special needs.

**Ergonomics and Task Analysis**

An observation technique called task analysis often is used to improve worker safety and the assignment of functions to a person or machine. Faletti (1984) and Czaja, Weber, and Sankaran (1992) applied this approach to the analysis of elderly persons doing a variety of everyday tasks ranging from bathing to shopping and meal preparation. Analyses of video recordings identified postures, movements, and forces that were difficult. The major dimensions of the physical environment in which the tasks were performed were also described. One of the important findings from this work was the identification of common actions such as bending, crouching, and lifting that resulted in difficulty in many different situations.

**Isoperformance Functions for Age**

Task analysis in the laboratory occurs in task simulators and participatory activities in which the participant directly manipulates environmental factors. In paced inspection tasks, for example, persons of different ages find the combinations of speed and frequency of target events that yield equivalent levels of performance, that is, isoperformance functions for age (Fozard, 1981). In vision studies for example, persons of different ages manipulate contrast and illumination levels to yield equal visibility functions. Steenbekkers (1998) came close to using this approach in her research on determining age differences in the size of type required by persons of different ages under various combinations of illumination ranging from 10 to 1,000 lux and contrast between letters and background ranging from 16% to 100%. The dependent variable in this research was type size. In the adaptive approach, the participant manipulates the levels of illumination and contrast required to read the text at a given type size.

**Customizing Products and Environments with Smart Technology**

There has been a steady development in the last half century in machines that learn (e.g., the development of checkers- and chess-playing machines that beat human champions and speech recognition
and production machines that learn to communicate with individuals). Application of smart technology to aging have focused on the customization of climate control and facilitation of communication (Bouwhuis, 1999). In contrast to ergonomic measures, which help older people adapt to difficult technology, the philosophy behind smart technology is that the technology can adapt to the needs and preferences of individual users.

Needs Assessments

Cullen and Moran (1992) conducted a pioneering analysis of technology in relation to four classes of human needs of older persons: social, medical, activities, and security. They evaluated technologies relevant to the four needs as met, not met, or inappropriately met. The results for technology from this perspective often were disappointing; however, the results have stimulated designers to address unmet needs as well as ergonomic issues in existing technology.

Surveys and Focus Groups

The prevalence of limitations in physical, cognitive and perceptual functioning increases with age. When surveyed, older persons are asked questions such as, “Do you have difficulty walking across the room?” “If yes, how much difficulty?” Refinements in surveys have increased their usefulness for gerontechnology applications for the compensation and, to a lesser extent, prevention of the challenges of aging. Verbrugge and Jette (1994) developed a model of the biological processes leading to disabilities that included the contribution of both personal and environmental factors. People with difficulties in carrying out activities of daily living (ADLs) and some instrumental activities of daily living (IADLs) reported using help from other people almost exclusively for limitations in upper-extremity actions; mechanical and environmental aids were used for some limitations in lower-extremity function.

Scientists at the National Institute on Aging and the Johns Hopkins School of Medicine developed the Physical Functioning Inventory (PFI) to provide specific information about how people adapt to limitations in function (Whetstone et al., 2000). The PFI consist of 22 questions covering activities ranging from strenuous to showering and bathing (e.g., “Do you have difficulty climbing 10 stairs?”) Answers of “yes” are followed with queries about assistive devices used, help obtained from other persons, modifications made in how or how frequently the task is performed, and whether health
problems are responsible for the difficulty. Responses of "no" are also followed by queries about how and how frequently the task is performed. In agreement with earlier studies, the percentage of self-reported difficulties in carrying out activities increases with age. Modifications in how tasks are carried out are more frequent adaptations to difficulty than changing the frequency of doing the tasks. Overall, 58% of the respondents who reported no difficulty in performing tasks had in fact changed how they performed the tasks. The value of the PFI for gerontology is that it provides specific information about what adaptations are made and what technology is used.

Rogers, Meyer, Walker, and Fisk (1998) used focus groups of older persons to address constraints in daily living and identify areas for ergonomic interventions. Responses were analyzed in four ways: (a) the locus of the problem (e.g., motor); (b) the activity involved; (c) the perception of why the difficulty existed; and (d) the response to the difficulty. Almost one half of the respondents reported adapting in some way to continue the activity, whereas the other reported giving up the task. These figures are comparable, with those reported by Whetstone et al. (2000). Rogers et al. (1998) estimated that 53% of the problems identified could be solved by task redesign (e.g., low-step buses, ergonomic chairs); training (e.g., driving, cooking, safe exercise), or both (e.g., using a credit card scanner, complex exercise machines, a computer, and a VCR).

Wahl, Oswald, and Zimprich (1999) studied the personal adaptations and environmental changes made by blind and severely visually impaired elderly persons. One questionnaire determined if persons could perform a variety of ADLs and IADLs in their homes. Each participant's home was rated by the investigators for safety and supportiveness of the physical environment. Only about 30%–40% of the home environments were considered to meet the criteria for high person–environment fit for the two groups. The ways that blind and visually impaired persons performed the ADLs and IADLs were scored as person related or environment related. Compared with the control group, blind or visually impaired persons reported more personal adaptations (e.g., spending more effort or time, using more latent skills such as hearing or tactile information, and simplifying their behavior). They also reported more environment-related compensations (e.g., visual prosthetics such as magnifiers) and adaptations related to light, legibility, and structure or order. This research is the most sophisticated approach to determining needs and habits of elderly persons with respect to needs for and uses of compensatory technology.
Usefulness of Assistive Technology in Home Care of the Frail Elderly

Mann, Offenbacher, Fraas, Tomita, and Granger (1999) compared the effectiveness and costs of providing assistive technology and home modifications to usual home-delivered nursing and support services in a group of frail elderly persons (average age = 74 years). The experimental group received technological products and/or improvements in their homes. The items provided were based on the results of a home assessment by a team that included an expert in home renovations. Participants in both control and experimental groups received a home evaluation and periodic monitoring of the home over an 18-month period. Outcomes measured included 18-month monitoring of functional status, use of home health services, and rehospitalizations; number of devices and home modifications made; and costs for institutional and home care treatment and support.

Over the 18 month period, physical functioning declined in both groups, but more so in the control group. Use of and costs for home nursing services as well as institutional care were significantly higher in the control group. Persons in the experimental group spent more on devices and housing changes than persons in the control group. Mann et al. (1999) concluded that the use of technological devices and environmental interventions were effective and less costly than the home health and institutional care provided to persons in the control group. The number of devices provided or acquired independently of the program in the experimental group was 729 versus 80 in the control group, a ninefold difference, or 15 versus 2 devices per person in the two groups.

FUTURE DEVELOPMENTS

There are several activities that are influencing the development of gerontechnology: a consumer-centered infrastructure for the development and distribution of technology, knowledge transfer and education, creation of professional organizations and publications, and strategies for paying and advocating for gerontechnology.

Consumer-Centered Infrastructure

The user should directly influence and, indeed, determine the direction of technology development and distribution because gerontechnology addresses how technology can meet the needs and interests of
a group of people—aging and aged persons. In other broad areas of technological application, experts serve as intermediaries between the end user and the technology. In environmental technology, for example, scientists determine acceptable levels of pollution, radiation exposure, or other environmental factors. In medical technology, experts in diagnosis and treatment determine the direction of technology development. The implication of this philosophy is that technological products, services, and environments need more user involvement. The success and usefulness of products can no longer be determined by responses of consumers who have little choice except to accept or reject a product. As indicated in earlier sections of this article, some training on the use of technological products is required. This suggests that a salon rather than warehouse approach to marketing may be more useful to older consumers trying to select technological products. Sales representatives need to perform more of a counseling and teaching function than is usual.

Knowledge Transfer and Education

Knowledge transfer refers to the movement of gerontechnology’s concepts and information between universities and research foundations on the one hand and industry, designers, students, consumers, and marketers on the other (Rietsema, Fozard, Graafmans, & Bouma, 1995). The knowledge transferred includes factual information about gerontechnology and the conceptual basis of gerontechnology (i.e., a consumer-oriented, scientific-based approach to technology development).

The synthetic, multidisciplinary nature of gerontechnology requires considerable flexibility in developing educational approaches. The authors of this article have developed a modular or building-block approach to curriculum development. Each of four modules—basic concepts of gerontechnology, information about people, information about technology, and pragmatics of gerontechnology—contains 7–10 sections of specific material that can be adapted to specific educational applications. This approach provides overall coherence to the curriculum as well as built-in flexibility. The building-block approach has been the basis for several very successful educational efforts in Europe. For example, the Gerontechnology Education Network in Europe (GENIE) conducts monthlong multidisciplinary courses in academic settings in two European countries involving faculty members and students from seven-plus countries (see Rietsema, 1998, for a summary). The website for GENIE is http://www.tue.nl/edu/genie.
Professional Organizations and Publications

In September 1997, the International Association for Gerontechnology was formed. It was chartered under Dutch law and provides the framework for periodic scientific conferences, publication of a journal and newsletter, and development and maintenance of a website (http://www.gerontechnology.org). In 1999, it officially sponsored the Third International Conference on Gerontechnology in Munich, Germany, and it will sponsor the fourth and fifth conferences in 2002 in Miami, Florida, and in 2005 in Japan. Before the Association was founded, two international conferences were held in 1991 and 1996 in Eindhoven, The Netherlands (Bouma & Graafmans, 1992) and Helsinki, Finland (Graafmans, Taipele, & Charness, 1998). Other organizations with significant activities related to gerontechnology include the International Ergonomics Association, the Technical Interest Group on Aging, and the European Chapter of the Human Factors and Ergonomics Association, as described by Fozard, Graafmans, Rietsema, van Berlo, and Bouma (1996).

Paying and Advocating for Gerontechnology

An enabling environment for aging has both social and physical components. For older persons in many countries the social component is publicly funded by government payments to elderly persons and/or to their professional and informal caregivers. Private savings, family members, and private charity pay for the remainder.

There are no similar support mechanisms for the physical component. In many countries, there is government support for the physical environment for special challenged groups (e.g., the blind, the wheelchairbound). At present, although the possibilities are significant, there is little support for the physical component of an enabling environment for aging by the private sector. One reason for this lack of support is poor understanding of the importance of the physical environment for aging. A second is agism in advertising and marketing, which are youth oriented, especially regarding technical products, environments, and services.

The United Nations (UN) declared 1999 the International Year of the Older Person. UN Secretary General Kofi-Annan stated, “A society for all ages is committed to creating an enabling environment for healthy life styles as people age.” UN activities related to the International Year of the Older Person included development of a global research agenda for aging and various social action agendas. The development of gerontechnology makes it clear that we should
add an environmental agenda for aging to complement and strengthen the research and social agendas (Fozard, 1999).

REFERENCES


