Impacts of technology interventions on health and self-esteem

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James L. Fozard, Impacts of technology on health and self-esteem. Gerontechnology, 2005; 4(2):63-76. Gerontechnology is concerned with the impact of four classes of technology impact on five broad classes of human activity: health and self-esteem; housing and daily living; mobility and transport; communication and governance; and work and leisure. The present review describes how the four classes of technology impact—prevention and engagement, compensation and assistance, care support and organization, and enhancement and satisfaction—relate to health and self-esteem. An ecological model of the changes that occur over time in the interaction between a people and their environments is presented. The time dimension of the model is shown to improve several other ecological accounts of the relationship between the environment and the health and well-being of people.

Keywords: technology, aging, self esteem, gerontechnology theory, ecological models of health and human functioning

GERONTECHNOLOGY AND ENVIRONMENTAL SUSTAINABILITY

Gerontechnology is concerned with the use of technology for the benefit of aged and aging persons. The theoretical underpinning of gerontechnology is a transactional account of the dynamics of person/environment relationships that occur with changes over time in the built, social and natural environments and how those changes affect the patterns of aging between and within the generations of people who create and use the environment.

Gerontechnology shares basic concepts of other ecological accounts of person-environment relationships, particularly as related to health and health promotion. Frankish[1] identifies several qualities of a healthful environment that affect human aging including: sustainability; energy use; renewable resource consumption; viability - air and water quality, contaminants; and livability - housing density and transportation. He points out that there is little research on how an aging population affects environmental resources or how physical environments serve as a context for values and definitions of well-being of older adults. The gerontechnology view on these topics is: "In the planning and managing process of urban environments, a number of sustainabilities are involved-economic sustainability, social sustainability, sustainable health and sustainable development. Gerontechnology especially addresses the last three mentioned".[2]

The main purposes of the present paper are: to review how the impact of technology relates to the ambitions and activities of aging and aged persons with special attention to the multiple roles of technology in health and self-esteem; to describe the transactional model that

provides the theoretical foundations of gerontechnology with special attention to its application to health and functioning; and to show how this model relates to several other ecological models that postulate how the environment is a determinant of health and well-being across the life span.

Impacts of technology on human activities

Gerontechnology concerns the direct impacts of four classes of technology on five broad areas or domains of human activity. The activities and impacts are conceptualized as a two-dimensional matrix as described by van Bronswijk, Bouma and Fozard[2,p.171] The five areas of activity are defined below.

Health and self-esteem - technology supporting physical, cognitive and emotional functioning as well as the treatment and prevention of disease. 'Self-esteem' refers to the use of technology to help maintain individual independence and dignity by reducing the direct dependence of an individual on other persons.

Housing and daily living - technology that supports independence, convenience and safety of everyday activities.

Mobility and transport - technology supporting personal mobility and the use of automobiles and public transportation.

Communication and governance - communication technology that maintains and expands social contacts as well as enhances the governance or remote monitoring of the health and functional status of older persons.

Work and leisure - technology that helps older persons to continue work and to enhance opportunities for educational, recreational and artistic activities.

Although the present article focuses on the applications of technology to the health and self-esteem of older persons, it will become obvious that the other domains of application are also indirectly related to health and self-esteem.

Impacts of technology on health and self-esteem

The impacts of gerontechnology for each of the five areas of application - including health and self esteem - are classified into four broad groupings which together constitute the practical goals of gerontechnology. Each of the four is defined below along with examples of their impact on health and self-esteem.

Prevention and engagement - technology to delay or prevent age-associated physiological and behavioral changes that restrict human functioning. It concerns accidents in and around the home and environmental factors contributing to allergies, depression and other modifiable conditions. With respect to health, "More so than in some other domains, the technological environment ranks higher than technological products in themselves. This approach asks for rather immediate investments for long-term societal results." [2,p.171] Prevention thus represents a public health use of technology that is most relevant to life style factors that affect physical strength, mobility and cognitive and perceptual functioning. Most applications of technology for prevention would be classified as primary prevention in the public health literature.

Fozard[3,4] has provided several analyses of the use of technology on prevention of which one example is summarized here--the use of technology to prevent problems of poor gait, stumbles and falls. Walking requires muscular strength, known to decline with aging, but strength is also modifiable by training into very old age. Ongoing research therefore may lead to a long-term intervention program designed to maintain a physiological reserve of strength required for walking. Unlike cardiovascu-

lar training, there are few strength training guidelines that relate the results of training directly to strength requirements for walking. Studies by Rantanen and Avela[5] and Kwon and colleagues[6] have established relationships between gait speed and leg strength that with some additional refinements could be used to set goals for strength training, for instance, the range of physiological leg strength reserve required for various gait speeds Further research is required to establish age-independent strength requirements for strength training programs.

Muscle weakness is not the only factor precipitating stumbles and falls. A recent study of gait analyses using motion sensors and dynamic analyses of stride and foot-walking surface contact indicates that many older persons used greater flexion of hip joints to compensate for relatively weak ankle strength, making them relatively more susceptible to stumbles and falls. The authors describe a simple way to obtain this important information that can be used in clinical settings[7].

Falls are infrequent and relatively unpredictable in most everyday situations. In an effort to measure walking in the seconds immediately preceding a fall, Tamura, Yoshimura, Nagaya and Chihara[8] and Yoshimura, Nakajima and Tamura[9] developed a lightweight, unobtrusive, wearable three-dimensional axial accelerometer that records fall direction, impact acceleration and fall time. The accelerometer is linked to a data logger and microcomputer. While the development is still in early stages, the device successfully identified 19 out of 22 falls amongst a group of older persons with Parkinson's disease.

The foregoing examples indicate the wide range of current and potential uses of technology in what would generally be considered primary prevention in the jargon of public health. The examples also illustrate the wide range of time intervals that may occur between the ascertainment of risk and the event.

Compensation and assistance - technology that compensates for age-associated losses in strength and perceptual-motor functioning[4,10]. Applications range from simple, 'one size fits all' mobility aids or large print-high contrast books to robotic and programmable equipment and products that adapt to the needs of individual users. This is the most frequent use in all domains of application, but especially so in health. "In the short run, these impacts may lead to sizeable reductions in societal costs of care".[2,p. 171] Most applications of technology for compensation would be classified as secondary prevention in the public health literature. Compensatory devices related to gait, stumbles and falls-rolling walkers, grab bars, hip protectors, motorized and manual wheelchairs and related devices--are continually being improved.[11] An increasing amount of sophisticated applied research is identifying the importance of vision and sense of balance for the compensation of age associated problems in gait, falls and stumbles.[12]

Advances in rehabilitation technology provide many products and environments that are potentially useful for older persons with functional limitations, but the extent and specificity of the contribution to the limitations by age is difficult to determine. Goals for design and therapeutic outcomes require a distinction between a specific recognized disability that limits function and limitation due to aging. Persons with functional limitations related to specific disabilities are as a group quite demanding of compensatory products and environments. In contrast, older per-

sons as a group often deny age associated functional limitations and as a result may not want to use devices that could be useful to them. The restrictions on coverage by health insurance and the specialized marketing of rehabilitative equipment often increase resistance to using compensatory equipment by older people.

Care support and organization - use of technology for self-care by elderly persons with physical limitations or by caregivers - often elderly themselves - of elderly persons with disabilities. Technological support of care-giving activities include devices that lift and move physically disabled persons, machines that administer and monitor the use of medications, and equipment that provides information about physiological functioning. Such products are used increasingly by nonprofessionals, for instance, family caregivers. The ergonomics of such equipment becomes increasingly important as the range of users increases. Aid to caregivers usually falls under the public health rubrics of tertiary or secondary prevention. Mann and colleagues[13] have demonstrated the cost effectiveness of multiple technological devices in prolonging the life and improving the quality of life of very impaired elderly patients with short life expectancies. In comparison to a control group, the availability of the technologies was shown to reduce the amount of nursing and institutional care required by the patients who were provided the technological devices.

Enhancement and satisfaction - the innovative uses of technology; for example, virtual reality, interactive communication devices and self adapting equipment that expands the range and depth of human activities with respect to comfort, vitality and productivity. It is most relevant to applications of work, self-fulfillment - artistic activities, education - and communication, all of which are related to self-esteem. "In the case of communication and governance, consider journals, radio, television, Internet, the cellular phone, or automatic translating devices as well as forms of citizenship making a more intensive use of the experience of older persons to enhance societal cohesion." [2, p.171] This area provides the most opportunities for new research and development in technology. Because enhancement emphasizes the roles of technology for expanding human activities, it transcends and encompasses the other three classifications of technology impact - those related to the public health goals of primary, secondary and tertiary prevention. For persons requiring use of a wheel chair, raising the seat height so that the person could face standing persons at the eye level of the latter rather than being forced to continuously gaze up to their face would increase the self-esteem of the wheelchair-bound person. Preparing and hosting a meal for guests would be another activity that enhances the self-esteem of elderly persons with limitations in physical functioning.

Theoretical foundations of Gerontechnology

Gerontechnology addresses the dynamics of the changes that occur over time in the environment and the aging people who create and use the environment. The projected changes in the relative distribution of ages across the lifespan in the 21st century are well known. Simultaneously, the rapid changes in technology experienced over the past century will continue, probably at a faster rate, particularly in areas of human activity where technology fulfills functions formerly provided by people.[14] This interplay between individual aging and secular changes in the environment is illustrated in Figure 1 and may be used in two ways: first as a

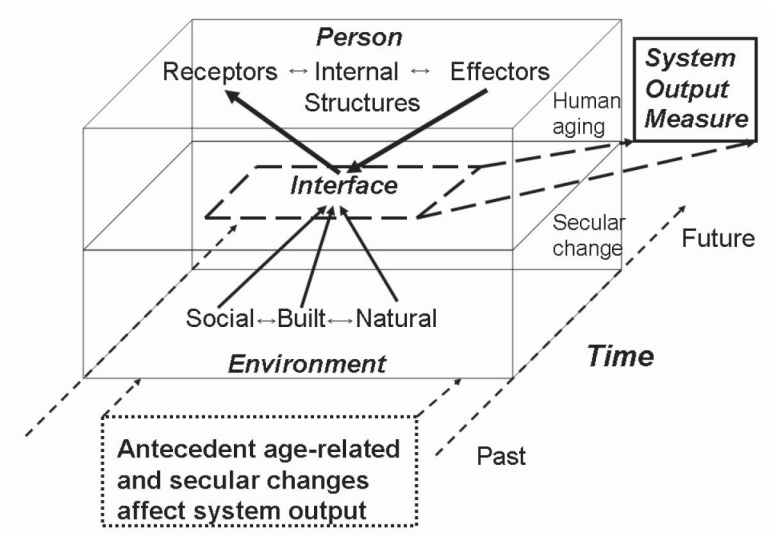


Figure 1. Person-environment interface and its changes over time. Information from the environment is received by the person via receptors, e.g., visual, auditory, and responded to via effectors, e.g., voice, movement of limbs. The environmental information comes from the built or manmade environment, the natural or physical environment, and the social environment. The result of the person-environment interaction is displayed as a system output measure, as shown on the right side of the figure. Over time the quality of the person-environment interface will change, partly because of age related changes in the physiological and behavioral characteristics of the person and partly because of secular changes in all components of the environment. Antecedent conditions affecting the person-environment interaction are shown at the bottom of the figure. The aging of a person born in one generation differs from that of a person born in a different generation. Adapted from Figure 1 in Fozard[18]

tool for analysis of the changing dynamics of person/environment interactions over time; and second as a means to compare the gerontechnology model to other ecological models of health as discussed later in this article.

Figure 1 is based on a core concept of ergonomics and engineering according to which people and their environment are considered as a system. The environment has three components - natural, built, and social - all of which affect the person-environment system. For present purposes, the person is shown as having three components - a sensory/perceptual component that receives information from the environment, an internal structures component that processes the incoming information, and an effector component that responds to the environmental information via voice, movement of limbs, etc. The interaction between person and device or environment is defined as the interface or user interface. It is represented in Figure 1 as the juncture of the upper (person) and lower (environment) halves of the diagram.

The arrows leading to the interface from the environment show that all components of the environment contribute to the system. The arrows on the person side show the flow of information from sensory-perceptual to effectors to interface. System performance or system output is represented by the rectangle on the right of the central person/environment diagram. Examples of output

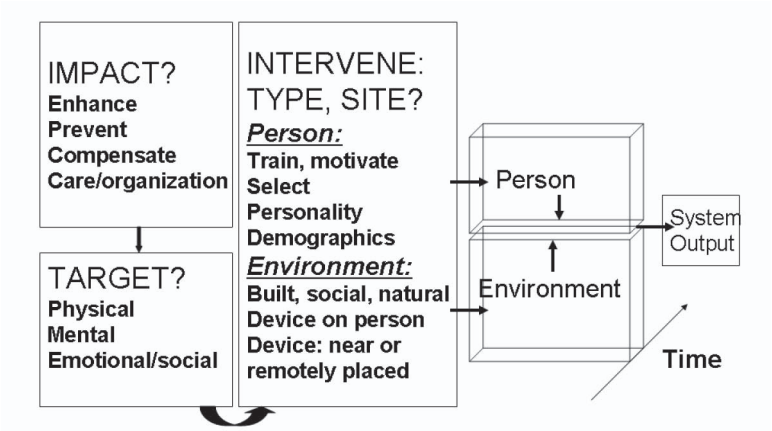


Figure 2. Planning aid for technology-based interventions for health and self-esteem. Choosing a specific technology-based intervention requires consideration of the type of impact desired, the intended target of the intervention and the type and site of the intervention. The process of choosing site - person, environment, remote - is borrowed from the formulation of Dishman, et al.[27]

measures include production errors, production rate, etc. System outcomes for health and self-esteem might include number of days without allergic reactions, speed of walking, frequency of successful telephone calls made or received without assistance by another person, etc.

System output can be held constant or varied by changes in the characteristics of the environment or machine, the way information is presented to or received from the person or a combination of both. Accordingly, the design goal for optimal system functioning is achieved by proper assignment of function to person or machine, adapting the devices used to present information or used to control or manipulate the machine, and selection and/or training of persons using the machine. For example, a given level of speed and quality of gait (system output) might be achieved by strength training to counteract age associated loss of strength (prevention) or by use of a mobility aid, e.g., walker or cane (compensation) or both when changes in the environment or aging of the person are taken into consideration.

The effects of changes in time on the dynamics of the person-environment system are represented by the two arrows in Figure 1 that portray the changes in a person that may occur with aging and those that occur with secular changes in the environment. Aging can refer either to different age generations or cohorts or to aging of persons in a specific age cohort over time. The important changes include declines in perceptual motor functioning and internal states including disease. The important secular changes in the environment are not limited to specific user interfaces in the built environment; they include changes in the social environment that provide the context for the user interfaces as well as the changes in the natural environment that affect sustainability. Both observational studies and laboratory research demonstrate that experience with one user interface can have negative or positive effects on the willingness of a person to use of another related or similar one, for instance, variations in the displays and controls of different automobiles or computer software systems. Prior difficulty with a technology based product may result in

avoidance or rejection of a similar product regardless of the ergonomic qualities of the latter.[15,16,17]

By itself, Figure 1 is a poor guide to specific applications. In order to facilitate the choice(s) of interventions, it is necessary to make a series of decisions such as those shown in Figure 2. A simplified version of Figure 1 is shown on the right side of the figure. On the left side are three boxes in the form of a flow diagram leading to the simplified version of Figure 1. Each box suggests the choices that need to be made. The first decision is the choice of impact - prevention, compensation, etc., as shown in shortened form. The second is the target of the intervention, for instance, the aspect of health and self-esteem that is the focus of the intervention, for instance, physical, mental, emotional health. Third is the choice of intervention - the person, the built environment/technical device, or a combination of both.

Gerontechnology compared to other ecological approaches to health and aging

The gerontechnology model presented in Figure 1 is not the first transactional model to be developed in research on aging. One of the earliest and most influential was created by the late Powell Lawton.[19] Lawton related his concepts of person-environment fit to those of gerontechnology in his opening address at the Second International Conference on Gerontechnology.[20] A later transactional approach to aging inspired in part by Lawton but based on human factors theory was published by Fozard and Popkin[21] and subsequently embellished.[10,22] The gerontechnology model described above improves on earlier such efforts in gerontology by including three features - the temporal dynamics of the person/environment interaction, the classification of technology based impacts, and the broad interdisciplinary approach.

Social Ecology Model

Gerontechnology focuses on the man-made environment but also considers the social and natural physical environment. Marshall[23] and his colleagues in Canada take another approach to linking a person to the physical environment. As shown in the top panel of Figure 3, his model links the individual in an ever-broader environmental network that ranges from interpersonal level to public policy. The physical and natural components of environmental influences on behavior are mediated through the social component of the environment.

In contrast, the gerontechnology model includes technology as part of interpersonal relations as shown in the bottom panel of Figure 3. The time dimension of Figure 3 adds to the comprehensiveness of Marshall's social ecology model. On the other hand the social ecology model adds important social dimensions of the environment to the gerontechnology account.

Surgeon General's Healthy People Model

Each ten years the Surgeon General of the United States publishes a number of public health goals to be achieved over a ten year period. The goals - targeted toward children, adolescents, adults and elderly adults - call for age-specific reductions in mortality, the prevalence of various diseases, limitations in access to medical care, accidents, and for changes in lifestyle, that reduce tobacco and alcohol use, and increase exercise. On successive decades, the Surgeon General reports on progress for the goals established earlier and develops new ones as appropriate. The discussion of the planned interventions in the Surgeon General's report employs an

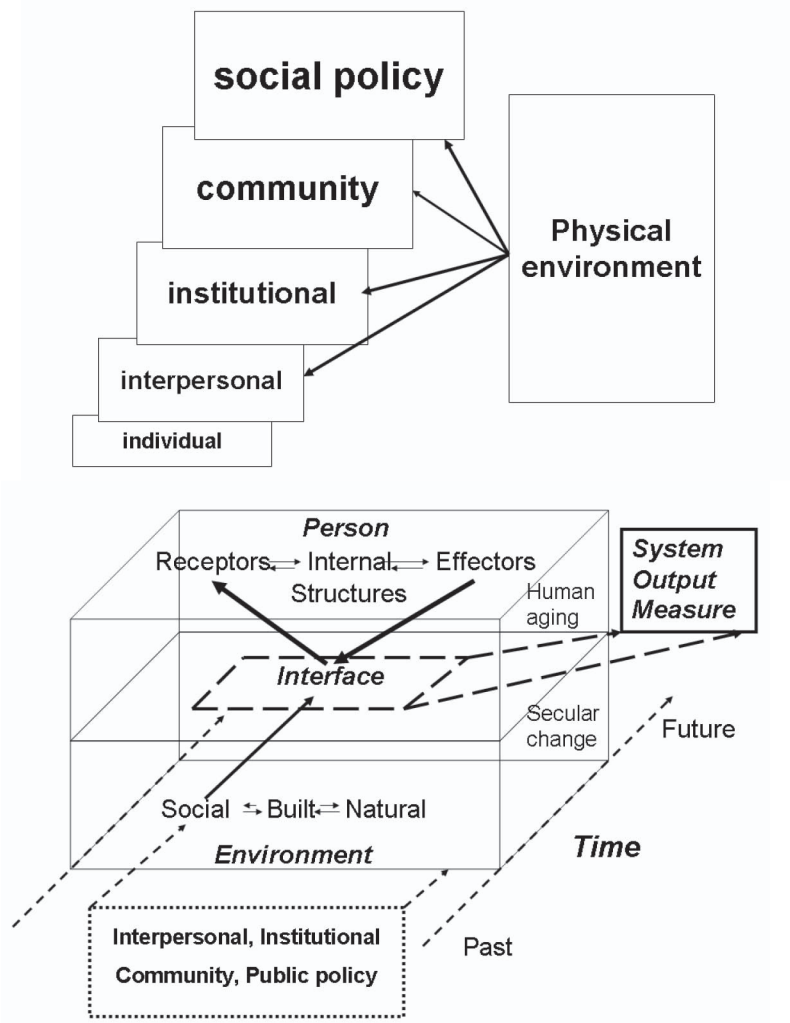


Figure 3. Social ecological model and its gerontechnology adaptation. ***Top*** *The overlapping rectangles show that a person's behavior and health is affected by various social interactions ranging from narrow interpersonal relationships through ever-broader social entities, e.g., community and social policy. In this model, the effects of the physical environment are mediated through social interactions. This figure was redrawn from one used by Marshall.*[23] ***Bottom*** *The social determinants of behavior and health are shown in the box at the bottom of the lower panel. According to the social ecology model, their contribution to the person-environment interface is through the social component of the environment - no direct arrows from the built or natural components of the environment are shown - rather the impact of the physical environment is mediated through the social environment. While the social ecological model does not specifically discuss the temporal aspects of the social factors, their role in determining behavior and health is subject to change over time. Figure 3 is adapted from Fozard*[22, Fig.2]

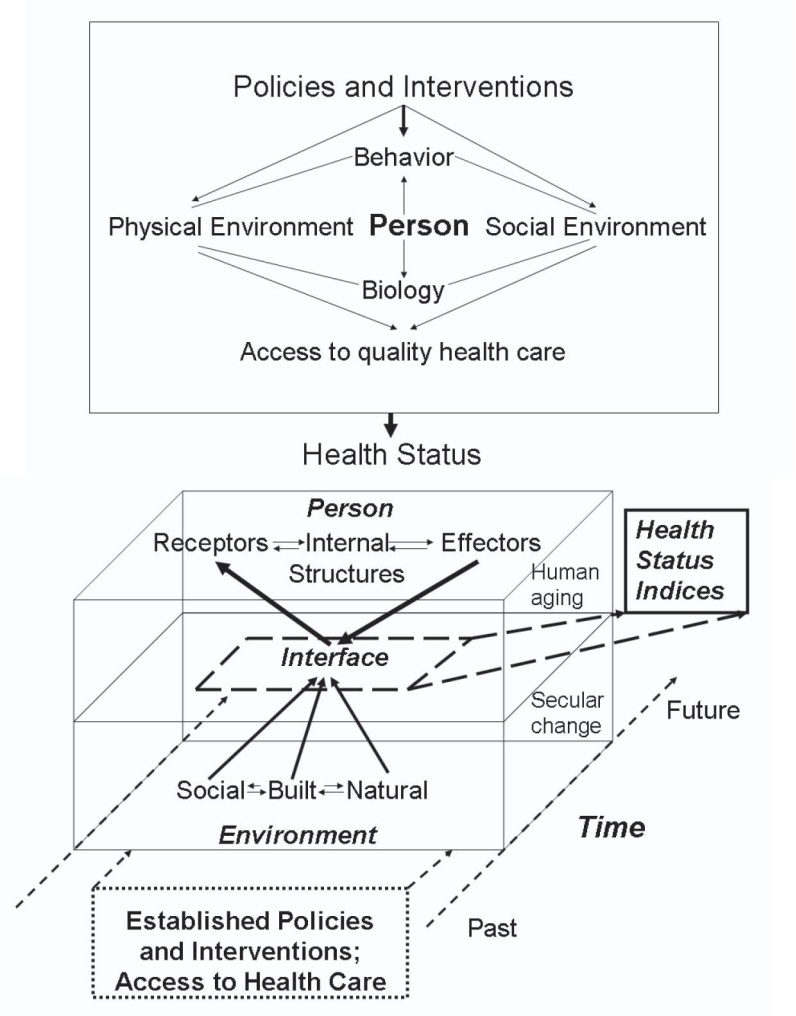


Figure 4. Detail from the U. S. Surgeon General's ecological model relating policy and public health interventions to health outcomes and the gerontechnology adaptation of this model. ***Top*** *A person's health status is influenced by the physical and social environment. The interaction is separated into behavioral and biological components, partly reflecting the role of medical intervention in health status. Public health policies and health interventions as well as assurances of access to medical care are seen as the means to alter health status. Indices of health status, e.g., number of teenage smokers, for each of the many public health goals to be reached by 2010 are described in Healthy People 2010. The figure was adapted from the one presented by Marshall.*[23] ***Bottom*** *The interaction between people and their environments shown in the Healthy People 2010 model is similar to that of the gerontechnology model. Over time, the policies and interventions as well as access to health care are shown as specific environmental determiners of the person-environment interface. The impact of the Healthy People interventions as well as all the other components will be reflected in changes in the various health status indices (arrow from interface to 'health status indices'), e.g., number of persons in different age groups who are hypertensive or overweight. Figure 4 is adapted from Fozard*[22, Fig.3]

ecological model of health as described in Healthy People 2010.[24] In this model, desired health goals and objectives are related to multiple determinants of health as depicted in the top panel of Figure 3, adapted from Healthy People 2010. The environment is divided into social and physical components connected to the individual by biological and behavioral pathways. Health related policies and interventions including those that improve access to quality health care are seen as modifiers of the person/environment interaction that affects measured health status (bottom of figure). Health status is operationally defined by several indices related to public health as well as morbidity and mortality. Changes in such indices measure the progress toward the attainment of the goals and objectives set for the decade. In this model, the interventions and access to health care correspond closely to the prevention, compensation, and aid to caregiver uses of gerontechnology.

The bottom panel of Figure 4 shows the relationship between the Healthy People 2010 and gerontechnology models. The public health policies and interventions as well as access to medical care are portrayed as environmental determiners of person-environment interactions as shown at the bottom of the lower panel of Figure 4. The health status outcome index (panel on right) displays the measure of the person-environment interface. The time dimension of the gerontechnology scheme captures changes in the health index resulting from the public health interventions. The gerontechnology version vividly illustrates that many factors - in addition to public health policy - influence the hoped for change in the health indices.

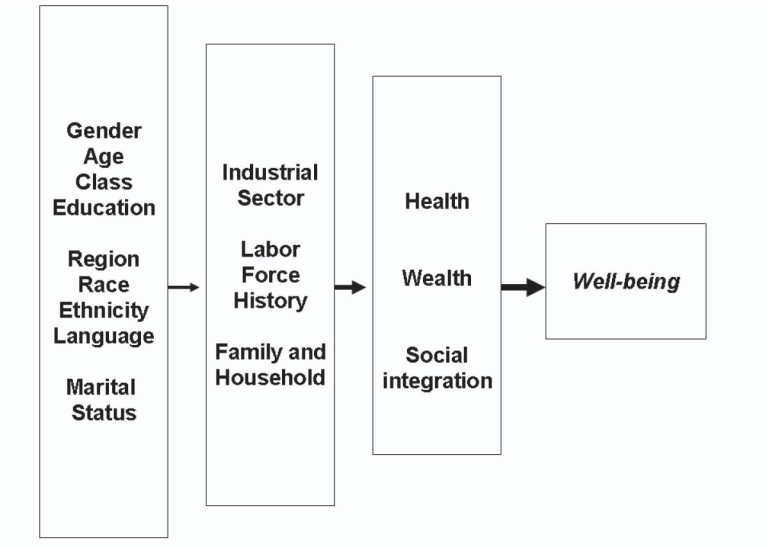
Healthy Aging Model

Marshall's[23] model of healthy aging relates individual well-being at any age to a host of demographic and personal history factors that contribute to health and social integration, that along with wealth, are considered the necessary proximal conditions for well-being. This model, redrawn slightly from Marshall,[23] is shown in the top panel of Figure 5. Although the term, 'environment', is not shown in the figure, the impact of the physical and social environment on all the factors contributing to well-being is easily discerned. Marshall's model is of particular interest to the present discussion because it proposes an organized hierarchy of historical factors in a person's life that contribute to well-being.

The relationship between Marshall's model and the gerontechnology model is shown on the bottom panel of Figure 5. Marshall's antecedent factors are listed as historical factors at the bottom of the lower figure. The most proximal influences, health, wealth and social integration are closest to the present in time, while the demographic factors are more in the past. The measure, 'well-being', is portrayed as an outcome to the right as a measure of the person-environment interface. Marshall's model suggests several environmental interventions across the life span that contribute to well-being in old age. The areas of application named in gerontechnology - communication, housing, work, health - are related to Marshall's factors of social integration, family and household, labor force history, health, respectively. Transportation and mobility cut across all of Marshall's factors.

Aging with a disability

Recently, ecological models of health oriented toward persons aging with a disability have been described.[25,26] The human component of the person-environment system includes personality and lifestyle, as well as medical problems secondary to the disability. Environment-



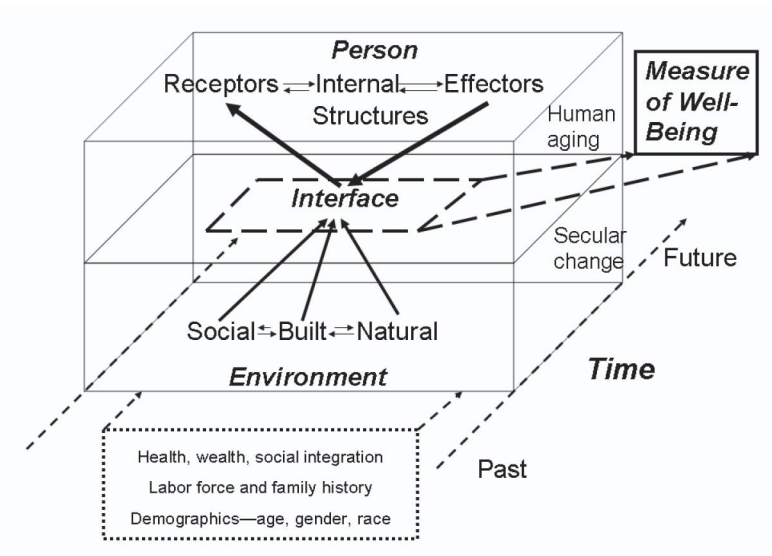


Figure 5. Marshall's health promotion model relating well-being at any age to determinants varying in proximity and importance and the gerontechnology adaptation.[23] ***Top*** *The most proximal influences are current health, wealth and social integration. Less proximal influences (not necessarily less important) include work and family history and various ethnic and social class factors. Although the factors contributing to well being are not specifically related to environmental factors, they could be. The top of Figure 5 is slightly redrawn from that presented by Marshall.*[23] ***Bottom*** *In the gerontechnology model Marshall's* [(23)] *determiners of well being are seen as historical factors having their initial influences at various past times in the life of a person. The dynamics of the influences of well-being can change as a person ages and the environment in which the person changes as well. Figure 5 is adapted from Fozard*[22, Fig.4]

al factors include social support, cultural background of the person as well as features of the built environment that support or challenge the person with a disability. Measures of quality of life are included in the outcome measures.

Technology and everyday health

Dishman, Matthews, and Dunbar[27] describe a model that with the exception of the temporal dimension, is very similar to the gerontechnology concept presented in Figure 1. They include two of the four impacts of technology used in the present model, primary, secondary and tertiary prevention; and, in place of the broad gerontechnology rubric of health and self esteem, four behaviors to be addressed by technology - health status, physical functioning, social interaction, and cognitive functioning. Their third dimension, called "site of operation," includes the person, the environment and remote. 'Remote' refers to monitoring of the person and their environment via video camera links, etc. Their 'site of operation idea' was incorporated into Figure 2.

Successful Aging, Baltes and Baltes, WHO Enabling Environments

Other concepts of health related to aging that extend beyond absence of disease share some of the conceptual elements of gerontechnology. The Rowe and Kahn[28] definition of successful aging includes 'maintaining high cognitive and physical function' and 'engagement with life' as well as 'avoiding disease' as the essential components. Baltes and Baltes[29] use the concepts of compensation and adaptation or accommodation in their eloquent analysis of changing responses to environmental challenges in the face of age related losses of functional ability. The World Health Organization definition of health promotion included the notion of the 'enabling environment' which in the gerontechnology model includes prevention, compensation and enhancement.[30] The WHO definition includes: "...the process of enabling people to increase control over and to improve their health... an individual or group must be able to identify and to realize aspirations, to satisfy needs, and to change or cope with the environment. Health is, therefore, seen as a resource for everyday life, not the objective of living."

Conclusions

Technology has a role in preventing or delaying age associated declines in health and functioning (primary prevention), compensating for such declines where possible (secondary prevention) and assisting persons experiencing declines for which compensation is not possible (tertiary prevention). Moreover, technology is used to enhance quality of life and independence at all three levels of intervention named.

An ecological model was developed to describe the changes in person-environment interactions that occur over time as people age and as the environment in which they live undergoes secular changes. To increase the usefulness of the model for planning technological interventions, some additions to the basic model were added that assist in the process of choosing the type, target and site of the intervention.

The gerontechnological model developed was compared to several other ecological models of health and well-being. It was shown that the temporal dimension of the gerontechnology model could be a useful addition to the other models discussed. At the same time some parts of the gerontechnology approach can be strengthened in various ways by the others discussed. Gerontechnology has a strong role in developing and improving the 'enabling environments for aging' envisioned by the Secretary General of the United Nations.[31,p.76]

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