Gerontechnology in perspective

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H.Bouma, J.L.Fozard, D.G.Bouwhuis, V.Taipale. Gerontechnology in perspective. Gerontechnology 2007; 6(4):190-216. Gerontechnology is directed at harmonizing two separate developments in present society: the increasing number of older persons, called the ageing society, and the technological innovation of products and services, called the digital era. Harmonization directs technological innovation to the ambitions, purposes, and needs of ageing persons. The knowledge basis of gerontechnology is provided by combining insights into processes of ageing individuals and ageing societies on the one hand and insights into new technological options on the other. The combination constitutes the field of gerontechnology. The present paper reviews a number of developments since the 1990s in the fields of gerontology, technology, and within the interdiscipline of gerontechnology itself. The cross-fertilization of gerontology and technology leads to a new matrix, in which progress, insights, and methodology specific to gerontechnology can be plotted. A selection of these is made on the grounds of their relevance to gerontechnology, irrespective of their initial scientific label. The review is not specifically directed at products and services suitable for older persons, although a few are mentioned in passing. The present knowledge base in gerontechnology is ready to be utilized for harmonizing demographic and technological developments.

Keywords: gerontology, technology, ageing, matrix, review, innovation

Gerontechnology studies the interaction of two dynamic developments in society occurring for the first time in history and in many countries: (i) the increasing preponderance of older people, due to increased longevity combined with a decreased birth rate, and (ii) the dynamics of technology, globalisation, and the rapid spread of a multitude of new mass-products. While the two developments occur simultaneously, their progress is mostly uncoordinated. Until now, technology has largely ignored the ageing population whereas quite a few members of the ageing population had neither the desire nor the skills to make use of the many new facilities. Nevertheless, technology and demography are bound to interact. Facilitation of this uneasy encounter is the core of gerontechnology[1-3].

Let us first focus on the ageing population. In industrial countries, average life expectancy has been increasing for over a century, leading to a substantial increase in the 65+ population, now standing at roughly 15%. Together with the decrease in the number of children, the percentage will rise to about 25% in the year 2025[4]. The older population will be in far better health than a few generations ago: substantial numbers will now reach 75-80 years of age with minor inconveniences only, notably restrictions in mobility. Governments have recognized the trend toward an ageing society, but rather than welcoming and promoting the tremendous opportunities, including those offered by new technological applications, the political response is to concentrate on expected problems such as increased pension burdens and the financing of increased care provisions. This may be an unhappy after-effect of the earlier prevailing sentiment that equated old age with frailty and withdrawal. It appears that this erroneous viewpoint persists despite the rising influence of ageing people in society in the years to come[5]. The reality is that the majority of 65+ people will be in good or excellent health, called '3rd age', and a far smaller number of older people in moderate or frail health, called the '4th age' [6], particularly in the final years of their life. Demographic projections indicate that in industrialized as well as most industrializing societies, both categories will grow substantially for many years to come. In the 75+ age category there are twice as many women as men. This is relevant to attitudes concerning technology innovations. In most non-industrialized countries on the other hand, young people tend to be demographically dominant.

Our second focus is technology. Arguably, the secular changes in industrial society over the last 150 years have been driven by developments in technology, such as new products, new services and their infrastructure, mass production and mass distribution, new materials and ever present embedded logic, globalization in direct communication, mobility, and transport. Recently, the high pace of technological change has accelerated further: the internet and evolving communication protocols invite the creation of ever more sophisticated networked applications[7,8], mobile phones with ever more functions, digital cameras, satellite TV, and widely available navigation systems; all these emerged in the last 15 years or so. Developments in technology exert both positive and negative influences on the living environment and on society, and substantial effort is being directed toward increasing advantages and reducing dangers. Whatever the advantages or disadvantages, what is relevant here is that the developments appear to be driven by autonomous forces outside the control of national and international governments, organizations, and business.

The core of gerontechnology is to study the interaction of the two developments. Ageing people are studied from the viewpoint of their living amidst a dynamic technological society. For them, technology is not an end in itself but a means to a better life. Technology is studied from the viewpoint of its potential to improve the life of ageing people and to facilitate their participation as full citizens in their own society[9-12].

Developments since 1990

The subject matter of technology and ageing has been on the research agenda for quite some time. Before 1990 or so, the combined consideration of technology and ageing focused largely on ergonomics, or human factors, for ageing persons and on assistive technology for people with physical restrictions[13-15]. This reflected the general feeling at that time that the aged and the handicapped could be viewed as a single category of people dependent on help and care.

From the early nineties, the scope widened substantially, witness the emerging concept of successful aging[16,17] and the development of gerontechnology[1,9,18-24]. The original themes stayed in focus, but the goals were set at a higher level. The term 'the handicapped' was replaced by the term: 'people with a certain restriction', to indicate that it is not the particular restriction that defines preferences, ambitions, and identity of a person, whether young or old[25]. As for those restrictions, we now want to concentrate on the extent to which these can be levelled or compensated for by specific technologies, just as spectacles compensate for poor eye sight, for example. Ergonomics or human factors for ageing individuals stayed on as well, but got to a higher level of development by recognizing the dynamic and widely varying nature of the ageing process and developing methodologies in which ageing persons played an active part. The main achievement of gerontechnology and related fields such as in human engineering was the insight that the ageing persons themselves come first and that their ambitions and needs should define the R&D agenda. If they wish to be independent and autonomous, let us elaborate what this means for the home environment. If they wish to communicate, let us see what internet, the web, and the mobile phone can contribute. If they wish to travel, let us work on easy public and private means of transport and the entire infrastructure that comes with it. If they wish to learn to use new technology, let us develop effective learning methods that will enable them to do so. Technology developments will teach us the domains where innovative products and services are entering the realm of serious options[26].

A selection of insights and methods that have served, and will continue to serve such purpose will be reviewed later in this paper. It will become clear that it is not just research and development (R&D) of products and services that is to change society, but also design and distribution (D&D), leading to an integrated RDD&D chain already well established in business and industry.

The interdisciplinary infrastructure subserving the field has been extended as well, both as special compartments of existing organizations in human factors and in gerontechnology itself. This is also reflected in the relevant handbooks[27,28]. A new journal appeared on technology and ageing[29]. The newly named field of gerontechnology gave rise to international congresses: Eindhoven 1991[19], Helsinki 1996[21], Munich 1999[22], Miami 2002[30], Nagoya 2005[31], Pisa 2008; to the European projects COST A5 and the educational GENIE project[32] followed by a textbook[9], to the establishments of the International Society of Gerontechnology in 1997, the quarterly journal Gerontechnology as from 2001, the gerontechnology discussion website[33], master classes since 2006, and many regional initiatives and workshops.

System approach and an impact matrix

The environment in which the young and the old live has been immersed in technology for well over a century. It follows that old people are quite at ease with technological commodities as such. It is the high pace of technological innovations that poses difficulty to many ageing people, who have to adapt to the ever dynamic environment. To the extent that technology is functional to meet human purposes, the functional result can be portrayed as a systems outcome, where the system represents the total of the human user and his/her technological environment *(Figure 1)*. Both the system and the user are dynamic: they are in constant change. The term 'ageing' catches the dynamic nature of the process of getting older. For the ageing user, these dynamics necessitate, among others, the lifelong learning demanded by the daily environment. The system approach pioneered by Chapanis[13,34] elucidates problems that have to be solved, such as the division of control between the technology part (automation, robots, virtual worlds) and the human part (choice of options), with the user interface as the technology that makes the human choice happen. The user interface has input and output technology functions which complement the respective output and input by the user, including processing arising from the internal states of both technology and user. Notice that the division of control and the user interface are just as dynamic as the whole system; that is the system itself as well as its parts constantly changing[35]. The interaction between ageing persons and their technological environment has several physiological and psychological aspects with consequences for the design process[11].

To make this rather abstract general scheme concrete, we have first to fill in the functionalities that represent system outcomes. So we turn to the main domains of life in which the technology has to function: health and self-esteem; the home environment; mobility and transport; information, communication and governance; work and leisure[18,36,37]. The main goals that we want to attain with the technology are the fulfilment of human ambitions and needs: enhancement and satisfaction of life, proactive prevention of disease and of functional restrictions, compensation and assistance, and finally proper support of necessary formal and informal care, including their organization. The five domains of daily life and the four goals to be served by technology together define an impact matrix, in which the various technology-defined products and services display their function for ageing people[36,37]. For each of those, the systems approach helps us to define what functional outcome we want, what the requirements are for the technology, for the user interface, and for the necessary human learning, given the important notion as well as the inescapable fact that the present depends on the past. With the vast array of options offered by embedded software, technology is made increasingly smart and adaptive so as to relieve users of demanding tasks and changing user control beyond recognition.

The present paper will review a number of relevant developments and new insights in gerontechnology as from 1990. The wider scope of gerontechnology particularly with respect to serving the ambitions, purposes, and needs of ageing people, furthering their independence and preventing illnesses of old age, has been well documented. Developments have happened in many fields, not all of which were labelled as gerontechnology. We will take the several gerontology disciplines studying ageing and the several technology disciplines as a starting point, and their combination will lead to a new matrix serving as a framework for a selection

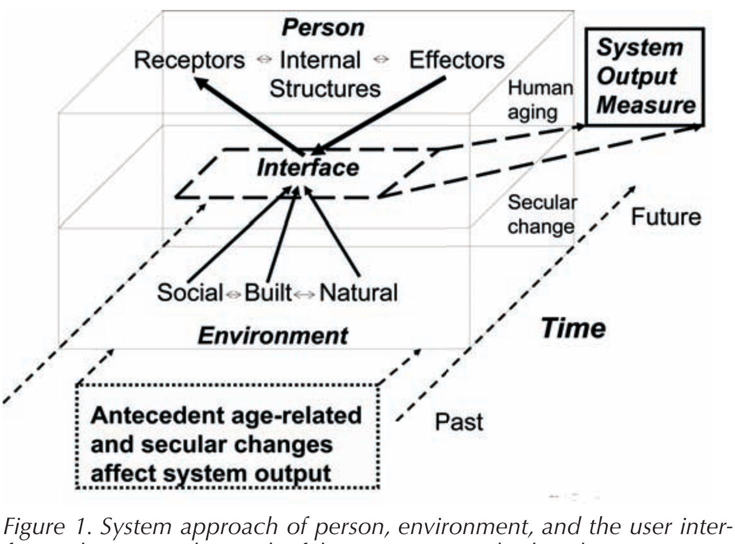

Figure 1. System approach of person, environment, and the user interface in between. The result of the interaction is displayed as system output. Note the role of time in all three layers, which makes the scheme essentially dynamic. From Fozard[35]

of defined progress in the general field of gerontechnology. Since we want to focus on insights and methodology gained, we shall not discuss the extensive range of products and services that are already or will soon become available for ageing persons, although some of these will be mentioned in passing.

GERONTOLOGY

Good ageing can be described as actively selecting among the many opportunities of later life and consciously living through adverse events as these occur. We use the term 'good ageing' rather than 'successful ageing', as the latter concept carries a history of interpretation and discussion[10,16,17] that we do not need here, although the elements of independence and autonomy are certainly valuable. Also, we will abstain from discussing the valuable concept of quality of life (QOL)[38,39], as this has developed mainly for the subject of health, which is too restricted for our present purpose. Good ageing rests on the following five individual pillars: healthy nutrition, daily physical exercise, regular cognitive and mental activities[40], maintaining social contacts inside and outside the family, and keeping an active interest in society. These largely correspond to three main academic disciplines that in combination address human developments including ageing: physiology including nutrition, psychology including social psychology, and sociology including demography. To these we add medicine including rehabilitation for dealing with restrictions and disease. The World Health Organization has a programme for healthy and active ageing[41].

Physiology of ageing

How does the human body develop with increasing age? Why does it age at all? Such questions are complex and the answers are only partly known. However, we do know that developments associated with ageing have their origins very early in a person's life, perhaps even at birth, and other adverse developments such as hardening of the eye lens occur somewhat later, but nevertheless before the age of 20. So ageing effects are not at all restricted to old age, say above 65, where our attention here is being focused[42-48]. Sensory aspects are concerned primarily with vision and hearing[49,50], but also include thermal comfort[51,52] and lighting effects other than on vision such as on mood (for instance, 'seasonal affective disorder')[53].

It is well known that daily exercise and/or training will keep the body in good shape. How critical is this factor, what are the individual differences and how can optimum exercise levels be achieved? Similar questions can be asked about physical endurance. In the absence of direct disease, can the decline of muscle power and of physical endurance be fully or largely prevented? In reality, difficulties of movement and of endurance rank high among the first restrictions experienced by ageing people[54,55].

Over the last decade there has been increasing attention to nutrition, be it for increasing healthy nutrients such as unsaturated fatty acids and anti-oxidants, or other nutrients leading to a low cholesterol content of the blood for preventing vascular and heart disease, or for reducing unhealthy nutrients, such as saturated fatty acids, which contribute to vascular disease whereas overweight contributes to diabetes. The list is gradually expanding as more diseases are shown to be influenced by certain nutrients. The view that certain genetic dispositions contribute to the likelihood of certain diseases is gaining influence. Obviously, the prevention of specific diseases of old age and general decline must start at an early age, if not directly at birth, then certainly well before the term 'old age' is applicable.

Psychology of ageing

Psychological functions develop with age[15,27,28,56-58]. This is true for basic perceptual skills such as vision and hearing, where recognition of the direct environment in its ever changing appearance has to be mastered by making likely selections from the available options, followed by decisions as to relevant actions. Interpretation of the surrounding visual, auditory, and haptic environment is a complex cognitive task in itself. If the environment is changing, perceptual skills will have to deal with it. The rise of visual and auditory media including virtual reality via so many TV channels, private videos, and internet/www applications signifies a changing general perceptual environment of which the consequences for ageing people are still to be assessed. In all cases, perception, action, and memory remain closely interwoven[43,59].

The changing environment applies just as well to language, the primary carrier of human communication. Just as is the case for the physical environment, the language environment is in continuous flux. These developments are now speeding up by mass media and new communication media such as SMS messaging. Such aspects are addressed by the psychology of language, a discipline in its own right, but here mentioned as part of social psychology[60].

Another important psychological function is human memory. Fortunately, there exists no upper age limit to learning, except in case of specific disease. Although 'forgetting' or 'access temporarily interrupted' (for example, specific names) is a common occurrence in humans, unlearning as a controlled process is difficult to achieve. So by necessity newly learned activities will rest on the basis of earlier learned activities, which therefore may interfere with the new ones. Relevant distinctions can be made between memory skills that are generally steady with rising age, including immediate (sensory) memory, long term memory ('knowledge'), and episodic memory, versus memory skills that tend to show a decline with age including (short term) working memory, and prospective or 'reminder' memory, which deals with events to be remembered at some future time[59,61].

Sociology of ageing

Sociology deals with group aspects of human communities rather than with individuals and their interactions. Demographics, i.e., the present and future age and gender composition of the population as a whole is basic to gerontechnology, providing information on the ageing population itself amidst younger populations[4,62]. The term 'generation' is relevant in defining people of a certain range of birth years or cohorts who have lived through the same general important events occurring in a certain stage of their development. These events may have a negative bearing such as war, scarcity, economic depression, widespread real or purposely induced fears, and political upheaval, or a positive bearing such as peace, general affluence, wellbeing, and political stability[63]. So, general economics[64], and in particular politics[65], belong to the sociological scene. Here, the earlier stereotypes of ageing persons as frail and socially dependent have only slowly been eliminated, partly by politically inspired thinking called critical gerontology[66,67]. Apart from the population as a whole, specific groups are being considered such as in household composition, education, economics, communication, public transport, paid or voluntary activities, computer skills, public provisions, needs, and ambitions[68]. Epidemiology will be classified here as part of medicine.

So we turn to these disciplines to learn about the lives of ageing persons: their health, their families, their housing, their mobility, their skills, their hobbies, their restrictions, their financial options, their activities, their communications, their networks, their interests, their drives, and the provisions of their communities[69]. On each of these aspects, we will have to find out what technologies are or will become available as tools for realizing their ambitions, meeting their needs, improving their health, and otherwise furthering their chosen life. An influential theoretical framework on how ageing people are dealing with changes in their environment has been developed by Baltes and Baltes[16], called a life-span model of selective optimization with compensation.

Medicine of ageing

Since health is such a primary factor of life, its absence is of primary concern as well. Geriatrics or geriatric medicine is combating the diseases that belong to advancing age. Examples are vascular and heart disease leading to restrictions in endurance, joint disease leading to restrictions in mobility, general pain that commands an overdose of self-attention, as does disease in general, eye disease such as cataract or age-related retinal macular disease, hearing disease, particularly in the higher frequency range, and the generally feared Alzheimer disease and other dementias. Often, different diseases occur together requiring the integrated approach specific for geriatricians and general practitioners. A great many innovative medical technologies for use by medical professionals have been developed, particularly in diagnostics such as medical imaging and in surgery such as joint replacements.

Epidemiology covers the overall incidence and prevalence of diseases and how these change over time and between specified groups of people or countries[70]. It is the basis for a proper understanding and assessment of effects of preventive measures in public health. Longitudinal studies in which substantial numbers of persons are being followed individually for many years have proven an effective means of identifying contributing factors to development of disease as well as its prevention[71,72].

An important area of technological progress is the general field of rehabilitation dealing with overcoming restricting effects of disease following surgery or accidents for instance. Formerly called 'aids for the handicapped', it comprises longstanding efforts to contribute to the life of ageing people. Also, several technologies have been developed for use by patients or clients themselves or their relatives, to combat the disease and to compensate restrictions. This is true for low vision[73], for hard of hearing[74], for mobility difficulties in walking, equilibrium, or endurance[43,55], for car driving[75], for mobility and transport[76], and to a lesser extent for memory problems and language difficulties in communication.

Technology

What types of technologies are or will become available for reaching the goals of good ageing? For this, we turn to the disciplines of technology.

Chemistry and biochemistry

Although often remaining in the background, chemistry together with physics provide the disciplinary base for the rapidly growing spectrum of materials and products in society. The new materials are stronger, lighter, more flexible, and integrated with embedded software. Pharmaceutical products constitute a special subset. The rapidly growing insights into complex chemical reactions and their catalysts and mastery thereof give rise to great expectations about general applications from which older people will benefit as well. The domain of biochemistry may have an especially important role to play as the impressive progress in understanding and mastering genetic and biological processes potentially leads to a wealth of new applications. It has been suggested that biochemistry may be characterized as the primary science of the 21st century, holding a similar ranking role to electronic and information sciences in the 20th century[77]. If so, one may marvel at such presently unforeseen developments.

Architecture and building

One's house is the most important place on earth. If only for the fact that many ageing people spend so much time in and around their house, building proper houses and making these a healthy, pleasant, and easy place to live, is an essential technology, and this remains true when restrictions occur common to old or very old age. In case of such restrictions, living independently rather than in institutions is an important contribution to actual and perceived autonomy and is highly valued. This extends to the suitability of the built environment around the dwelling, that should both be an agreeable and easy setting, and provide access to essential commodities and services. The domain of the house as potent supporter of independent living has also been targeted by communication technology[78,79]. A subfield of this, related to security, safety, and general remote control is called smart housing or domotics[80].

Communication and information

The information revolution in society of the second half of the 20th century heralded by progress in information science, electronics, and miniaturization has given a decisively new face to the whole society, to many subdivisions, and in the final decades to individual citizens. Older segments of the population have been slow to profit from the many new options in communication and information handling because they were generally unaware of the advantages, untrained in the complex user interfaces, and not targeted in the marketing campaigns which were, unfortunately, dominated by technical details rather than by useful functionalities. The audio CD and the home computer were forerunners, but it took the infrastructure of the internet and its applications for cheap and immediate language communication over vast distances (e-mail) and for getting useful information (via search programmes) to arrive at the present myriad of applications for collaboration, games, picture exchange, sound access, marketing, and so many other services producing the recent revolution in digital cameras, mobile phones, and mobile web access, which the young generation is already taking for granted. The concept of wireless communication derived from remote controls and mobile telephony continues to gain ground; however, wireless power transfer technologies remain around the corner. The older generations are now gradually following suit, albeit somewhat hesitantly[81].

In the mean time new applications are arriving at full speed. Particularly since the information revolution, ever more types of products and services are affected by integrated functions and hidden embedded systems software. Ambient intelligence will soon be an omnipresent invisible commodity in the human environment, penetrating all aspects of life, and also changing the lives of ageing people[82,83]. The area of virtual reality deserves special mention as the boundaries with physical reality are getting increasingly blurred. Before long this will also apply to direct human communication, as smart programmes will make virtual communication through programmes including language and speech technology very realistic.

Mechatronics and robotics

Mechanical engineering was the overarching term applied to this endeavour until the information revolution changed its appearance into mechatronics and robotics. Miniaturization is the key element of contribution of these disciplines to information sciences, thereby providing society with the means to put on a new face. Now, invisibly embedded and distributed logic can be hidden everywhere and include sensors and effectors for controlling the environment and providing a plethora of choices between automation and user control. The field has contributed in particular to rehabilitation, as the compensation of physical restrictions in activities of daily living (ADL) has profited greatly from mechatronics and robotics[84], and the science of creating artificial limbs has evolved beyond recognition.

A special domain of application within

this field is transport. In particular in many types of public and private vehicles with their extensive infrastructure a high degree of innovation is evident. Driven by the need for safety and comfort of users, cars have been forerunners in applying automation while leaving the driver in the drivers seat[75]. Tinker[76] has provided an insightful paper on the importance of mobility and transport of ageing people and on the many problems encountered.

Design and ergonomics

Design is the core of products and services. It is not just concerned with outward appearance, but involves the integrated aspects of materials, production, functionality, user control, maintainability, and appearance[85]. The user interface is the part that enables user control and can be considered the heart of the functionality as experienced by the user. The general aspects of products related to the user are dealt with by ergonomics, human factors, or human engineering. This field is long known to provide essential expertise in the development of products and services for ageing users[86-90]. The valuable concept of inclusive design, also called universal design or design for all, originates from the design discipline and will be elaborated later. Unfortunately for ageing people or consumers, in real practice ergonomics has often been disregarded in product development for reasons of legacy problems, professional ignorance or unwise cost reduction.

Business management

Management science has established itself as an indispensable enabling discipline to bring the fruits of technology to the global market place, and ensuring that the products, services, and infrastructures are realized. The proper organization of innovation, production, distribution, and marketing is a major feat of recent global economies. In product innovation, the younger population has received most of attention so far. It may have escaped attention that many ageing people are well-to-do, as a group controlling the lion's share of private capital. As soon as the ageing populations are targeted as a worth-while market segment, a whole range of new products and services can be expected. In industrial countries, the older segment of the population combines a critical attitude and diverse interests for new functionalities with an overall sufficient purchasing power. New skills and management focus may be necessary for successfully addressing the ageing population[91]. There are clear signs that industrial forerunners are now working towards this goal[82,92].

Cross-fertilization matrix

The combined disciplines of ageing and of technology lead to a matrix of disciplines, the cells of which provide the positions where the actual new insights and innovations for ageing people can be visualized (*Table 1*). Of course nothing is static within such a matrix: it simply shows where knowledge, insights, and methods are to be found or developed necessary for the task at hand. The matrix may also serve as a tool to select the professional skill and methodology necessary for choosing and working toward useful technology products and services for the target group of ageing people, and to develop proper training schemes for the intended users.

We will now consider a selection of matrix entries, i.e., relevant developments for gerontechnology, in a coarse time frame with intervals of 5 or 10 years, and starting around 1990. Some of these stem directly from research, development, and design in the field of gerontechnology; others have originated elsewhere. The common feature is their great potential for contributing to a good life of the ageing population. Each of the cells of the interdisciplinary matrix may reflect existing and new insights, methods, and activities. The selection of content for the matrix cells chosen in Table 1 may change or increase over time, reflecting new insights gained and methods developed. Below, we will explain our selection criteria. The indicated years provide a rough estimate of the time when relevant gains in insight and methods were obtained.

Understanding ageing users

Situated learning (1990+)

[One matrix cell: Psychology & Information/Communication]

Teaching yourself user skills from a booklet, by attending a theoretical class, or by following 'directions for use' appears far from effective[93]. Situated learning[94] refers to learning neither in a classroom nor from 'directions for use', but by getting automatic guidance in the actual situation that one wants to control (learning by doing). This appears to be more motivating and also more useful, since one feels in control from the very start of the application process. Wizards and situated computer prompts are special case examples of this approach. The design of such situated learning systems is a demanding task and has to be based on validated experimental findings. Animation may present a method that resembles or emulates situated learning[95-97].

Technology generation (2000+)

[Three matrix cells: Sociology & Information/Communication, Mechatronics / Robotics, Ergonomics/Design]

The prime time to development of general physical, mental, and social skills is roughly up until the age of 30 (formative period); more complex skills -including social ones- can be acquired later when demands of the working and living environment specifically require them. Whereas young people may learn new skills easily, old people must learn them while disregarding earlier mastered skills that cannot easily be unlearned. Therefore, ageing people are at a disadvantage when dealing with new technology, particularly if they have not had the opportunity to learn such new skills in the context of their daily work and life. People with a low or moderate general education are at a disadvantage as compared to people with a higher general education. Since the level of general education has risen over the last century, many ageing people have not been in a position to receive higher education. This contributes to the generation effect: it is not just age itself that may stand in the way but also the environment, education, and training of the generation to which one belongs and the type of skills acquired during one's childhood, adolescence, adulthood, and older age. The general sociological concept of 'generation' thus may get applied to the common technological environment during the formative years. This is the general background of the notion of 'technology generation'[98].

Research has shown that in consumer goods the type of user interface used before the age of 30 or so, either of the mechanical or the electrical type, remains present in one's mind and habits and may interfere with using later types of user interface such as menu-driven ones[99,100]. The concept of 'user interface generation' also indicates that the difficulties of ageing persons to deal with new control concepts are unlikely to disappear in the future when most ageing people will have had extensive experience with menu interfaces, for example in their jobs. It is the dynamics of technology innovation that will continue to cause difficulties for people of generations that have learned to control the former type of user interface. The system concept referred to earlier is well suited to cover this type of difficulty.

Apart from the user interface, there will be other aspects of technology that may show generation effects such as the functionalities of telephone, radio and television, the internet, and mobile phones. The general term 'technology generation' is then the guiding concept covering 'user interface generations', 'functionality generations', and other effects still to be found[101].

Table 1. Cross-fertilization matrix of gerontechnology. The four rows indicate the main discipline groups of ageing processes (gerontology); the six columns the main discipline groups of innovative technology. The matrix cells contain a selection of concepts, insights, and methodology that are relevant to gerontechnology. Some of these belong to more than one cell. All are detailed in the text.

		Technology					
		Chemistry Biochemistry	**Architecture Building**	**Information Communication**	**Mechatronics Robotics**	**Ergonomics Design**	**Business management**
Gerontology	**Physiology Nutrition**	Preventive nutrition	Experimental houses Healthy indoor environment	Telecare	Biorobotics Resource sharing (man-vehicle)	Individual differences User participation Inclusive design Standardisation	Care management innovation
	Psychology Social psychology		Experimental houses Domotics	Situated learning Temporal discount & benefits Technology acceptance Persuasive technology Domotics Navigation tools		Individual differences User participation Inclusive design Standardisation	Technology acceptance Persuasive technology Targeted marketing
	Sociology Demography			Technology generation (protocols)	Technology generation (protocols)	Technology generation (user interface)	Targeted marketing
	Medicine Rehabilitation	Preventive drugs Perceptual implants (materials)	Healthy indoor environment	Perceptual implants (signal processing) Modelling restrictions Telecare	Biorobotics Resource sharing (man-vehicle)	Self medication Telecare	Care management innovation

Temporal discounting and benefits (2000+)
[One matrix cell: Psychology & Information/Communication]
The basic paradigm for temporal discount is that future rewards are less valuable than immediate rewards. As a consequence the value of a certain reward decreases with future time. The effect can be measured experimentally by equalizing the value of a future higher reward with an immediate lower reward. For ageing people, this temporal discounting has an extra dimension because they take into account the expected though unknown number of remaining years of their life. Therefore, ageing people with poor health apply higher temporal discounting than healthy people of the same age *(Figure 2)*. This is perfectly logical behaviour. In practice it means that expectations on the total effort necessary for learning a new task now should be balanced against expected rewards of actually using the acquired skill in the future[102-104]. Therefore, ageing persons may be perfectly rational when they have reservations about technological innovations: the future benefit of the promised functionality has to be compared with immediate cost, be it financial cost or effort for mastering the user interface. If only for this reason, the user interface for ageing people should be designed to be as easy as possible.

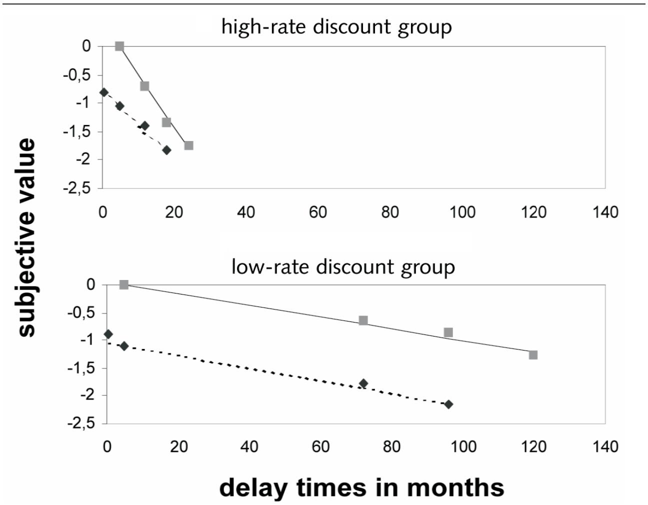

Figure 2. Temporal discount functions of favourite and second best holidays (upper and lower lines respectively) for a high rate (upper figure) and a low rate (lower figure) discount group. Response strength of attractiveness in logits. From Melenhorst[103]

Nevertheless, an easy interface is not sufficient for ageing people to accept new technology that may be of great functional benefit to them. It appears that people need clearly discern the benefits of a new product before they want to try, use, let alone accept it. The greater the perceived benefit, the less important the quality of the user interface becomes[102].

Experimental houses (2000+)
[Two matrix cells: Physiology, Psychology & Architecture/Building]
Demonstration or model houses are in standard use for a long time, but ‘houses of the future’ too have been around for a while, usually showing fantasies of the present rather than previews of the future. In certain countries sample houses have been produced for public visits that are meant to offer realistic views of feasible new features including ways to make provisions for physical restrictions, also taking into account their cost effectiveness. However, new types of experimental houses have been conceptualized and realized which are not intended as a blueprint of the future but as an experimental R&D tool for finding out what type of housing and useful provisions would attract the elderly[105-107]. This seems to have accelerated the mass realization of certain internal and external features of houses, since their potential value can be assessed beforehand. If combined with carefully considered inclusive design, many older people may want to use these experimentally identified useful features, all the more if they are properly normalized, mass-produced, and widely distributed.

Designing for ageing users

Individual differences (1990+)

[Two matrix cells: Physiology, Psychology & Ergonomics/Design]

Individual differences generally increase with age because of different life experiences and life situations of individuals. This makes that each adult human is a unique person with individual ambitions and needs. The increase in individual differences with ageing concerns a great many physical, mental, and social factors including ones that have negative connotations such as a low income, a narrow job experience, loneliness[108], or a certain chronic disease. As to the latter, Alzheimer's disease and other types of dementia are relevant examples[109-111], as are visual and auditory restrictions[50,112,113]. In macro-descriptions such extensive individual differences are sometimes disregarded, for example in anthropomorphic, demographic, or epidemiological data. In using such data for the design of products or services, this can easily be misleading. The so-called 'average fallacy' in ergonomics is that almost nobody exists who is average on all counts. The greater the number of dimensions taken into consideration, the fewer the number of people who can be classified as average. For example, if on each dimension 67% of the population is considered 'average', this percentage shrinks to 9% if six independent dimensions are being considered together. The general message is that the spread and the lower and upper limits of the particular target group are at least as important as grand averages.

User participation (1990+)

[Two matrix cells: Physiology, Psychology & Ergonomics/Design]

Given that there are many unknowns about ageing people and that both individual differences and cultural differences may be substantial[114-116], several recommendations can be made. Firstly, ageing people of the target group should participate in the design process for which several scenarios have been described such as focus groups and drama sessions[117-122]. Secondly, choice options or adaptation to individual preferences and differences are valuable[113,123]. In general, these aspects have been incorporated in the concept of inclusive design.

Take memory aids for example. Although diaries and calendars are classical memory aids, their equivalents in the information age like palm tops and address and telephone lists on computer, have not yet been able to fully replace them, certainly not for the older segment of the population. This is partly due to inadequately designed user interfaces, but more basically this may be due to insufficient research in what added practical benefit ageing people could get from such aids. All technical options are available, but a lack of really appropriate functionalities (such as useful reminders), as well as an overdose of less useful functions, are witness to the lack of insight into memory restrictions in daily life of ageing people.

Inclusive design (2000+)

[Two matrix cells: Physiology, Psychology & Ergonomics/Design]

New technology, certainly in consumer products, has usually been targeted at the young generation who are supposed to be receptive, dynamic, and perhaps less critical in accepting new products as compared to ageing adults. Often the designers were young as well, designing for people their own age and for their own generation, which they understood so well from within. Advertising for new technologies openly breath this atmosphere of youthful enthusiasm, thus excluding ageing consumers implicitly and perhaps not always unintentionally. This is augmenting generational differences at the disadvantage of older generations.

The remedy for this has been called universal design[124,125], design for all, or, the name preferred here: inclusive design[89,126-133].

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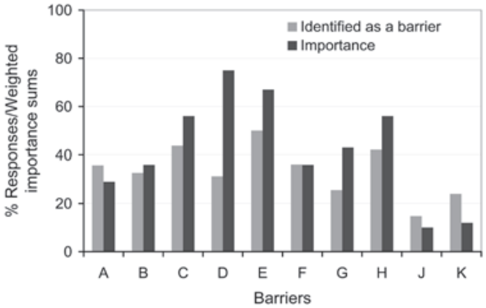

Figure 3. Ten barriers to inclusive design in companies with their estimated importance; A= lack of internal support; B= requiring cultural change; C= lack of knowledge; D= lack of business case; E= lack of time/budget; F= too difficult; G= compromises aesthetics; H= not perceived end user need; J= stigma; K= unachievable. From Goodman et al[136]

The concept is that if a design is directed toward users with lower skills, those with higher skills can also easily use it. The concept has been developed at the Royal College of Arts in London[133,134] and extended elsewhere, such as in the EU funded GENIE project[32,36,135]. Inclusive design cannot really be for everyone: there will be limits in perceptual, motor, and mental skills beyond which the design cannot be used without help of others. Therefore the choice of skills included requires an explicit answer, to be corroborated by the involvement of a carefully selected group of users to be included[127]. From a professional point of view, applying a relevant selection of the extensive body of methods and insights in design is a must[128,136,137], however, not always receiving the required attention *(Figure 3)*.

Standardisation (2000+)

[Two matrix cells: Physiology, Psychology & Ergonomics/Design]

The great value for the ageing user of normalization and standardisation in related products from different sources is obvious[138]. The main relevant base document is ISO/IEC Guide 71[139] which needs to be translated into more concrete design rules *(Figure 4)*. The importance of standardisation in general becomes clear from a great many products in which this is already applied such as in car control, and in a negative sense from products where this has not yet been achieved such as in early domotics. Many new products teach us that in practice it can take several years or more before normalization is actually implemented. Since the learning of new skills becomes more difficult in old age, lack of normalisation is detrimental particularly for ageing people. Also, deliberate efforts to unlearn certain skills are bound to fail as more often than not the extra attention paid to unlearning in fact makes the presence of that old skill more apparent than ever. New types of products should not try to distinguish themselves by a new type of interface unless the latter is substantially easier to use than alternative solutions. Standardisation should be based not just on the technology but on proper insights and experiments on the broad target groups of users as well[140].

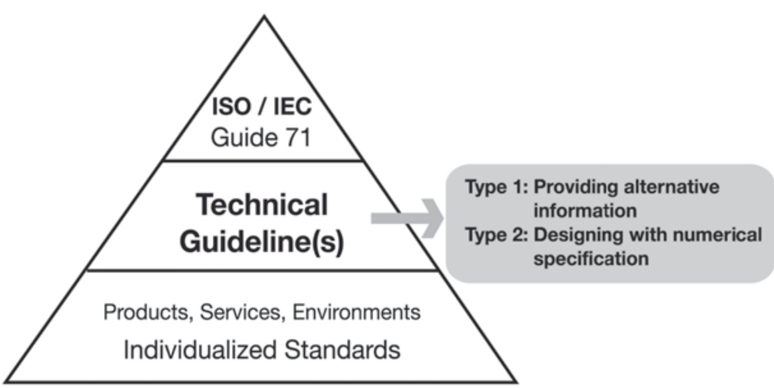

Figure 4. ISO-IEC Guide 71 is concerned with the needs of older persons. Technical guidelines translate Guide 71 into practical design fields. From Sagawa[138]

CONVINCING AGEING USERS

Technology acceptance (2000+)

[Two matrix cells: Social Psychology & Information/Communication, Business Management]

The problem of non-acceptance of new technology specially designed for increased usefulness neither by older people, nor by youngsters has given rise to theories of acceptance. An influential one is the Technology Acceptance Model (TAM)[141]. It states that the behavioural intention to use a product is determined by its perceived usefulness and its ease of use. Both of these are subjective constructs, and may deviate considerably from more objective measures of usefulness and usability. In that sense the model is a somewhat indirect measure of the tendency for real technology adoption. Nevertheless, perceived usefulness has been consistently found to relate strongly to usage intentions[142,143] *(Figure 5)*. The authors reported four longitudinal studies in which they further explored which factors contributed to perceived usefulness and to perceived ease of use. Social influence appears to be a major factor, described as the person's perception of what people important to him feel he should do, or not do. On the cognitive side, prospective users should have a clear perception as to what the product can do for them, and how well and effectively it will function. So while demonstrations of comparative effectiveness seem crucial, these should include the explicit endorsement of their peers, or even be demonstrated by them.

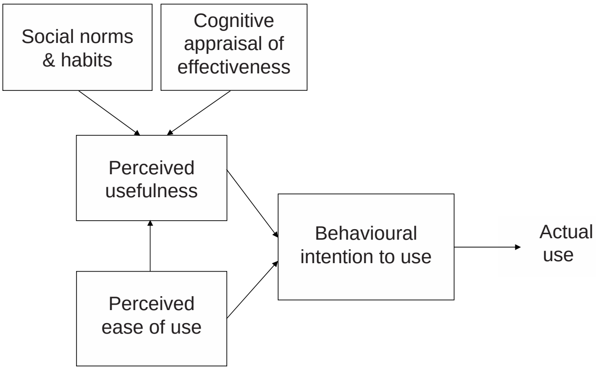

Figure 5. Diagram of the Technology Acceptance Model after Davis[141] and Venkatesh et al.[143]

Persuasive technology (2005+)

[Two matrix cells: Social Psychology & Information/Communication, Business Management]

In contrast to functionality, motivation is a somewhat underestimated aspect of ageing persons' appreciation (positive or negative) of certain products or services. Persuasive technology[144] tries to lower the psychological barrier by providing intrinsic motivation. The intervention can be realized in several ways such as by situated advice or immediate rewards. Social connectiveness is one of the areas of application, for example by stimulating intergenerational contact and by telegames. Perceived benefit must be the real drive for ageing people[79]. The boundary between overt and hidden persuaders needs to be monitored to avoid unrealistic expectations or actual disappointments[145].

Targeted marketing (2005+)

[Two matrix cells: Social Psychology, Sociology & Business management]

This is an area eagerly awaiting development[91]. Tools for marketing for specific age groups are well established, especially those aimed at young people. Targeting ageing consumers is more complicated because of the many specifics, most of which have been outlined in the earlier sections on inclusive design, technology acceptance, and persuasive technology. As to financial aspects, a substantial part of private capital is controlled by ageing people, but at the same time ageing people constitute a substantial part of the society's poor, thus generally suggesting that there are large individual differences in this market. The rising use of internet/www applications by ageing people offers an extra opportunity for interacting with them. Areas where ageing people have already been discovered by marketers are banking and travel.

Prevention

Preventive nutrition and drugs (2000+)

[Two matrix cells: Nutrition, Medicine & Biochemistry]

One way to remain in good health is healthy nutrition, exemplified by the saying: 'an apple a day keeps the doctor away'. Over the last decade the value of these good eating habits has been increasingly recognized. In particular the need to maintain a diet that includes the types of food that contribute to health or, conversely, a diet that excludes foods that contribute to disease. An interesting example of this knowledge is the use of so-called anti-oxidants such as certain vitamins and traces of metals such as zinc. The idea is that the ageing body is less able to neutralize the oxidants that are accompanying energy processes in the body[146,147]. It turns out that indeed quite a few diseases of old age can be connected with this type of process. Of late, even age-related macular disease (AMD), that used to be classified as incurable, has been shown to develop more slowly in response to a proper diet established years earlier[148]. New insights in genetic factors related to the presence or absence of protection for specific diseases can be expected to lead to more effective individual preventive measures such as specific diagnostics and drugs.

Healthy indoor environments (2010+?)

[Two matrix cells: Physiology, Medicine & Building]

A healthy indoor environment is being threatened by a number of invisible dangers such as insufficient ventilation, excessive humidity in the kitchen, and mites in textiles. The situation has recently worsened due to a reduction in the number of air vents to improve energy efficiency. It is wholly within the reach of present-day technology to avoid such unhealthy situations by using control systems that get their input from devices such as humidity and carbon dioxide sensors and providing output to effectors controlling natural and forced ventilation[149-151]. Remarkably, battery operated effectors for opening windows with wireless control are not yet mass-produced, since these would make dynamic control of air composition in each separate room possible. This would be helpful for all ageing persons, and in particular for people with lung diseases such as emphysema. In fact, most present 'air conditioning' systems are crude temperature conditioners only.

Domotics (2000+)

[Two matrix cells: Psychology & Architecture/Building, Information/Communication]

Domotics can be defined as the semi-automatic handling of house functions such as security, safety, alarms, indoor climate, and the concomitant user control. Basically, domotics uses proper sensors and effectors combined with embedded software and distributed intelligence. Domotics has gradually grown in significance and many partial solutions are on the market[80]. However, network standardisation including the selection of protocols (for instance internet protocol IP) and the characteristic of the user interface is still far from realized. Also certain elements are not yet widely available such as the standard effectors for opening and closing windows, mentioned earlier, that are integrated into the automatic air quality control systems in separate rooms including the kitchen. This hampers application on a large scale; standardisation and mass-production are necessary to bring costs down and induce general acceptance within the population. Domotics also seems to suffer from insufficient understanding of actual practice. Experiments are needed to identify which of the many possible functions deliver added value and deserve to be implemented on a large scale. The field is maturing slowly but progress may be expected in the next decade.

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COMPENSATING RESTRICTIONS

Biorobotics 2005+

[One matrix cell: Physiology & Robotics]

The field of robots for direct use by ageing people is still in its infancy, robots being considered as automatons with a degree of automobility and adaptivity to the environment. Daily-task robots on the market include vacuum cleaners that navigate through rooms and grass-mowers finding their own way across the lawn. Both these devices perform similar physical tasks. Quite different is the 'robot-pet' that may help to satisfy the need for personal affection without the difficulties involved in handling live animals[8] *(Figure 6)*. It seems likely that robots will perform a more general semi-automatic control function in the environment, responding to the user's handling preferences with different types of adaptive programmes from which the user can choose as he/she likes by giving instructions to the device. The notion of manifold 'butlers' that has been proposed for household machinery in general[83] seems particularly suited for personal robots that not only perform a required task but also induce positive feelings in the user because the required task is carried out in the desired way. This requires an interface that mimics aspects of the communication between humans[152]. It goes without saying that biorobotics is of the utmost importance for compensating physical restrictions[84].

Figure 6. The adaptive robotic harp seal Paro[8]

Perceptual implants (cochlear 2000+, vestibular 2010+?, visual 2010+?)

[Two matrix cells: Rehabilitation & Chemistry, Information/Communication]

Cochlear implants have been developed in the nineties primarily for deaf children. Sound is picked up by a microphone, analyzed, and transmitted to an electrical stimulation unit with thin electrodes very near the cochlear nerve. Although normal hearing cannot be restored, the additional hearing function has proved to be very effective. The success has inspired ear surgeons to apply the same technique to certain types of deafness in ageing people, again with reasonable degrees of improved hearing functions[74]. Perhaps, the technique might also become applicable in cases of vestibular deficiencies.

For vision, the situation is more difficult if only because the optic nerve carries a million fibres as compared to about 30.000 for the auditory nerve. Nevertheless, efforts have long been directed at realizing the goal of restoring at least minimal vision for blind people with residual retinal function. The recent advance of image sensors, exemplified in digital cameras, as well as implanted electrodes has given rise to new efforts using visual implants from which also ageing people may benefit. For all types of perceptual implant, the problems that have to be solved must begin with medical and sensor technology. Basically there are two types of visual prostheses, those functioning in the retina, and those stimulating the visual brain areas. The retinal implants are also of two types, epiretinal and subretinal, where the subretinal systems essentially mimic the role of the cones. The number of light sensitive cells is still very limited, in the order of 5x5, but new developments suggest a potential layout of 60x60. Power delivery to systems in the moving eyeball is an acute problem. It is sometimes supplied by a wireless coil or by means of thin flat cables hugging the eyeball[153]. Epiretinal systems are mounted on top of the retinal layers and stimulate the underlying ganglion cells, but need an external camera that may be mounted either in a pair of spectacles, or even in the eye lens itself. Many engineering problems will have to be solved before such systems can be successfully employed.

Pioneering work by stimulating the visual cortex directly has been done by Brindley and Lewin[154]. Their subjects reported seeing phosphenes, small bright dots that behaved in a regular manner as a result of stimulation. Later, microelectrodes were actually inserted in the visual cortex which obtained a resolution five times higher[155]. All mentioned systems require complex surgery, either in the eyeball or on the brain tissue; transcranial magnetic stimulation (TMS) is a non-invasive and painless method that can modify or modulate neural activity. For these systems also an external camera is needed. It should be realized that these methods currently offer a visual resolution of no higher than 0.05 of decimal acuity (20/400) but mostly much lower. Nevertheless, for some people this will provide a considerable improvement of their visual capabilities. The image that people see is not at all a simile of the natural scene around them, and far less so in the case of visual cortex stimulation that lacks the pre-processing of the retina and the lateral geniculate nucleus. As the external cameras move in conjunction with the head, or with the eyeball itself, subjects can recognize movement relatively fast, and -after some training- also approaching and receding objects. Nevertheless, the follow-up with training for interpreting the artificially created sensations in terms of the outer world has to be carefully prepared and carried through, for which a suitable theoretical framework will have to be developed[156].

Modelling restrictions (2000+)

[One matrix cell: Rehabilitation & Information/Communication]

It seems intuitively obvious what a particular physical or mental restriction means in practice: hard of hearing, low vision, low endurance, and memory difficulties. But it remains to be seen to what extent this accords with real restrictions. Modelling the restrictions is a possible way of objectively comparing subjective and actual restrictions. The reliability of this methodology depends on the validity of the theoretical and experimental basis of such modelling. Good results have been obtained for modelling colour anomalies (colour weaknesses) for which suitable theories exist. The models permit calculation and presentation to persons with normal colour vision what actual colour differences persons with different types of colour anomalies can see or distinguish. Recently, the method has also been applied to modelling low vision of different types[157] *(Figure 7)*. This software has been made freely available and permits designers and architects to get a far better idea of the consequences of their designs for people who have to live with such restrictions. The methodology lends itself to a much wider range of restrictions in perception. It would be interesting to find out if this method can also be extended toward a selection of age-related restrictions in motor and psychological functions.

Navigation tools (2000+)

[One matrix cell: Psychology & Information/Communication]

Navigation tools are a recent accessory to cars. Automatic adaptation to current road and traffic situations can reasonably be expected to expand gradually and this may be of great help to ageing people as well. Cycling could follow suit (2005+), although a number of difficulties still need be overcome. For pedestrians, particularly in cities, a suitable and robust navigation tool is urgently needed. Such a system would help people with mobility restrictions to find the shortest route and people with visual restrictions to navigate independently. In fact all older and younger people could then find their way in poorly known environments. In order to reach

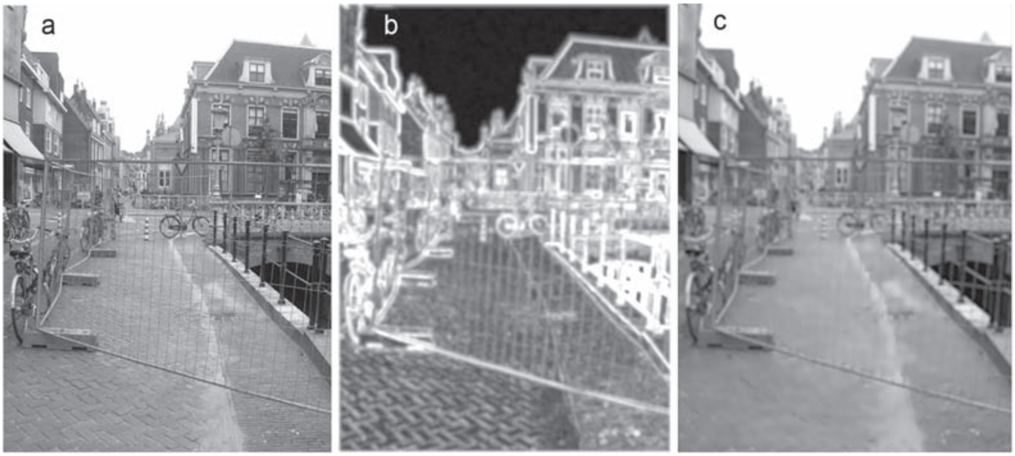

Figure 7. Modelling low vision. The effect of applying a local blur linked to local contrast: (a) original image; (b) a measure of local contrast determining the amount of blur via the contrast sensitivity function; (c) the result of the local blur transformation. From Hogervorst et al.[157]

this goal, a number of difficulties will have to be overcome such as permanent availability of navigational signals in densely built environments and increased display adaptability to indicate the presence of permanent and temporary obstacles. For the user interface, a number of problems will have to be solved such as the format of instructions by the user and the different types of detailed feedback of the recommended routes[158,159].

Resource sharing (2000+)

[One matrix cell: Physiology, Rehabilitation & Mechatronics]

Hybrid power systems in cars are gaining ground for reasons of energy efficiency. For a different purpose and using different technology, hybrid cycling is on the rise[160]. Here, the power is being supplied partly by the cycling person and partly by a silent electrical motor. What is interesting is that the motor is only supplemental, i.e., it is active only in combination with actual cycling by the person and adds a certain percentage of power only. The added electrical power can be adjusted so as to address adverse environmental circumstances such as a head wind and cycling up a slope. Present rechargeable battery technologies are sufficiently powerful for about 100 km if no excessive weight is added. This development makes it much easier for ageing people to continue cycling, for daily purposes such as shopping, but also for exercise and leisure. Since bicycles need a certain speed for a stable equilibrium, the auxiliary motor also contributes to safety. The advanced equilibrium technology developed for a fully automated scooter might be partly useful for bicycles as well (equilibrium sharing). It is perhaps somewhat far-fetched to think about a similar power sharing for walking, i.e. the technological equivalent of a supportive human arm rather than the low-tech walker. The smart walker was perhaps a forerunner of this technology[161].

Care support

Self-medication (2010+?)

[One matrix cell: Medicine & Ergonomics/ Design]

Correct adherence to a self administered medical drug regime may present a real problem even if the patient is fully cooperative. Automatic memory aids can be combined with a system that provides the right drugs at the right time[162]. This will be an improvement over the current prevailing situation where patients are effectively left to sort it out themselves. However, the problem is complicated if accidental or deliberate underdose and overdose are to be excluded. Conceivably, microtags could be developed that would enable direct remote registration of the real intake of medication[163].

Telecare (2000 +)

[Three matrix cells: Physiology, Medicine &, Information/Communication, Ergonomics/ Design]

Although telemedicine is perhaps best considered an issue of medicine, telecare is certainly within the scope of gerontechnology. A striking example is the use of video links in telecare provision. Initially there was scepticism due to concerns over the issue of privacy protection, since the older person had no control over who was watching her or him. But carefully designed experiments dealing with this issue have made clear that video links are perfectly acceptable for clients provided that its actual use is for strict necessities only and the clients are fully informed about the technology and when it is actually applied[164,165]. For specific services this condition is automatically fulfilled, for instance in the form of the so-called 'good morning' service where clients are contacted by videophone every day at a fixed time to enquire after their health status or special demands. The 'good morning' service is considered to be a close substitute of a real conversation; while it is explicitly stated that the call service is available on a 24/7 basis, clients practically refrain from making calls after five o'clock in the afternoon or before nine in the morning, which they feel to be 'impractical' or 'impolite' for the call desk. Such measures are not just cost-effective, but offer options for increased communication that can be exploited on a large scale. Telecare is now entering a new period for both professional care and for informal care provided by family members, friends or neighbours.

In a number of locations in Europe, video communication is used for telemedicine; diabetes medication being the most common. Patients self-administer glucose with a diabetes pen, the frequency or time of which may be dependent on weight, glucose level, or blood pressure. Instructions on how to handle the various devices can be provided by specialized nurses, who see the patients perform the measurements on their monitor, or they can demonstrate how to do it. While this seems an efficient procedure with a potentially wide application, there are many problems that still need to be solved. These problems reside on a number of levels that call for a much more integrated design process of such complex systems. Glucose level, for example, is measured by taking a drop of blood from a small cut with a sharp tip that is to be removed from its sterile packaging. Especially patients with bad eyesight, which is common in diabetes, have trouble doing this, and frequently patients are not able to draw blood successfully. The various measurements have to be registered in a computer system that engages in a dialogue with the user which can produce either incomprehensible statements ('invalid measurement: negative weight') or clearly untrue statements ('no patient data') when all data have been filled in.

Any setback of this kind that reduces the patient to forced helplessness diminishes the trust in and acceptance of such systems to a considerable degree, even if the occurrence of such messages is relatively rare. This is not a biochemical or medical problem but a typical design problem, where it is imperative that the design should concentrate on robustness, intuition, and reliability as the most basic requirements of the product. Even the most simple and intuitive interface is pointless if the system itself is unreliable.

Care management innovation (2005+)

[One matrix cell: Medicine/Rehabilitation & Business Management]

The goal of care management is high quality care, i.e., well timed, friendly, and effectively geared towards the needs of the individual patient. Efficiency is another important consideration. There are increasing options for tele-tools such as passive and active alarms, self-measurements and semi-automatic communication of physiological variables, and video-communication, involving telecare[166,167]. Also tele-instruction may be utilized far more than is presently the case. Together with navigation tools[167] this is bound to influence the organization of care. The boundaries between professional care, informal care, and self-care are increasingly fluid due to the influence of the many new options offered by technology. The dynamics will draw on the innovative capacity of care management.

To elaborate: it is hugely underestimated what the transition to more automated care and self-care will mean for care providers. As a rule, care providers financially do not have the investment capacity to change the care process, as well as the fact that they will have to care for both those clients that need traditional physical care and those for which a telecare system has to be maintained. Also the national or regional financing schemes of the care providers may not allow changes or diversification, or make those difficult. As a sobering thought, it should be kept in mind that in most European research projects on telecare and telemedicine the actual cost of care provision has been much higher than those of providing traditional care. None, or very few of the telemedicine projects can currently run in a cost-effective way, compared to traditional care. This means that much research and development (R&D) is needed, not only on cost-effectiveness and functional effectiveness of telecare, but also on care models that can be sustained against the background of the existing legal and financial framework or/and are so convincing that even the legislators are forced to embrace innovation.

Conclusion

We are living in an era of unprecedented exciting progress in technological options that are changing many aspects of present society at a high pace beyond recognition. We are also living in an unprecedented era where absolute numbers and percentages of older persons are increasing at a marked rate. The technological revolution has put the growing generations of older persons at a disadvantage if only because their life-long experiences have been shaped by their experiences in earlier technological environments. However, it appears quite feasible to bridge the gap between ageing people and their present environment if only efforts are focussed toward that goal.

The knowledge base for informing such actions is the combination of the disciplines of ageing (gerontology) and the disciplines of technology. In the second half of the 20th century efforts were initially directed at two important fields: ergonomics or human factors for ageing persons and aids for the handicapped. From the nineties, the knowledge base has been expanded as other ambitions and needs of ageing persons have been taken into account as well. This is the field of gerontechnology, bringing gerontology and technology together for the purpose of a good life for ageing persons, most of whom can be independent and integrated in society.

Seventeen years of gerontechnology have produced many new insights as to opportunities and obstacles or challenges in bringing the fruits of technology innovation to the large and growing older segment of the population. In this paper a number of recent insights and methods are being reviewed that are ready to be utilized in products and services contributing directly to a good life of ageing persons. Given that gerontechnology is interdisciplinary by nature, a cross-fertilization matrix between gerontological disciplines and technological disciplines can serve as a mapping device. Increased efforts in gerontechnology are necessary to keep pace with the rate of technological innovation against the background of prevailing cultural attitudes in the various ageing societies.

This review is directed at developments in industrial and industrializing societies but the global nature of technology and the relatively low cost of digital communication and services makes its findings relevant for other societies as well.

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