Age and cohort effects in gerontechnology: A reconsideration

James L. Fozard PhD[a]
E: fozard@tampabay.rr.com

Hans-Werner Wahl PhD[b]
E: hans-werner.wahl@psychologie.uni-heidelberg.de

[a]School of Aging Studies,University of South Florida, Tampa, Florida 33260 USA; [b]Institute of Psychology, Department of Psychological Aging Research, Heidelberg University, Bergheimer Strasse 20, 69115 Heidelberg, Germany

J.L. Fozard, H-W Wahl. Age and cohort effects in gerontechnology: A reconsideration. Gerontechnology 2012;11(1):10-21; doi:10.4017/gt.2012.11.01.003.00 **Background**: Information about aging used in gerontechnology has two main sources. Longitudinal, experimental, and to a limited extent cross-sectional research addresses technology-relevant differences and similarities in people as they age. Other research designs such as cross-sequential methods compare generational or cohort differences in people of different ages compared at the same time. Information from both sources are needed in gerontechnology, but frequently the age interpretation is dominant, though this may not be warranted. **Goals**: (i) to show how person-environment interactions that change over time are related to multiple age and birth cohort effects, and (ii) to identify how longitudinal and cross-sectional information on aging can best be used in gerontechnology. **Method**: We review the dynamics of changes in person-environment interactions in relation to several cohort and age effects. We differentiate among: (i) nonspecific cohort effects, e.g., increasing longevity; (ii) specific cohort effects important in gerontechnology, e.g., increasing health and functioning in cohort flow; and (iii) technology-related cohort effects, e.g., changing attitudes toward technology in cohort flow of older adults. In addition, we suggest four areas to consider of age effects, i.e. (i) sensory and motor functioning; (ii) cognitive performance; (iii) personality and self; and (iv) motivation and emotion, and discuss the interplay of such cohort and age categories in gerontechnology in exemplary manner. **Results and conclusions**: It is important to simultaneously consider the impact of the various cohort and age effects to major domains of gerontechnology, i.e., housing, communication, personal mobility and transportation, health and functioning, work environments, and recreation and self-fulfilment. **Applications**: By identifying the best evidence about aging and cohort effects as related to technology, gerontechnology can improve the practical applications for technology use in old age.

Keywords: longitudinal & cross-sectional research, person-environmental interactions

Gerontechnology is ‘the study of technology and ageing for the benefit of a preferred living and working environment and of adapted medical care of the elderly’[1(p12)]. The composite of two words - ‘gerontology’, the scientific study of ageing, and ‘technology’, research on and development of technically based, products and environments - has two foundations. The first is the applied sciences underlying technology, e.g., computer science and electronics which in turn are derived from more basic ones, e.g., physics and chemistry. The second is gerontology, the scientific study of aging. A relatively new and synthetic field itself, gerontology primarily builds on the basic and applied sciences related to biology, psychology, sociology and geriatric medicine. This paper, mostly arguing from a gero-psychological point of view, relates the sources and content of gerontological information to gerontechnology. Human aging brings changes in functioning, motivation, and well-being, hereafter called age effects. The goal of gerontechnology is to modify such changes with interventions oriented toward prevention or compensation and optimization of such changes[2]. In addition to such an age focus, it is important to acknowledge that members of successive birth generations, hereafter referred to as age cohorts or cohort effects, will in some ways age differently depending on changes in the environment in which aging occurs. Some writers refer to age cohorts as technology generations[3,4].

This paper starts from the observation that interpretations according to age have gained dominance in gerontechnology, although this may not be justified in many constellations. For example, referring to age differences when it comes to efficient use of the internet is problematic, because respective socialization and learning experiences have been very different between younger and older ages. In spite of that this is all well-known[3,4], we argue that the interplay of age and cohort is not taken seriously enough in gerontechnology. In addition, age and cohort effects need a differentiated view, but seldom receive it in the day-to-day business of gerontechnology research and practice. Therefore, the major purpose of this paper is to demonstrate the importance of identifying and distinguishing among a variety of different age and cohort effects. There are several age effects related to stability and positive growth as well as deficits in human functioning so the uses of technology for fun and improvement of quality of life are equally important as those that compensate for deficits[5]. Similarly, the range of cohort effects, currently defined mostly in terms of technology generations, needs to broaden. Changes in health, longevity, education, and social relationships are changing the applications and appliances of gerontechnology.

The paper has four parts. The first briefly reviews the gerontechnology matrix - the five domains of application as well as the major goals of gerontechnology[6] emphasizing the rapid changes in technology in all five domains. The second expands a current description of a person-environment transactional model of technology use[7,8] and discusses the commonly used sources of scientific information about age and cohort effects. The third enriches the transactional model with a more differentiated view on age and cohorts. The fourth develops a framework that links such a differentiated age and cohort view with major domains of gerontechnology, followed by recommendations for future gerontechnology research and practice. This paper is dedicated to Herman Bouma, who has contributed many groundbreaking contributions to gerontechnology starting with the seminal book edited by Bouma and Graafmans[9].

Domains of application and goals

In order to provide the fundamental substance, from which our suggestion to better consider age and cohort effects presented below can draw from, we start with a short referral to generally acknowledged areas and goals of gerontechnology. Five major areas of application of gerontechnnology are shown in the rows of the matrix (*Table 1*)[6,10].

The domain of health and self-esteem covers the full range of physical, cognitive and emotional functioning as well as the maintenance of individual independence, self-efficacy and dignity. Housing and daily living addresses the home environment as a major environment of aging, in which about 70% of young-old and about 85% of old-old individuals' daily activities happen[11]. Mobility and transport have found to be key to older adults' quality of life as well as their experience of autonomy and participation[12]. Communication and governance covers the maintenance and enhancement of social relations as well as the governance of communication including that of the role of being a senior citizen. Finally, work environments for older employees, given the well-known demographic development in

Table 1. The gerontechnology matrix. Four goals of technological interventions (rows) in five domains of human activity (columns) are depicted. The entries in each cell identify one intervention that was available in the 1990s and a newer one available in 2010+. Entries in each cell selected from the several identified in Tables 2 and 3 in Bouma, Fozard, and van Bronswijk[6]

		GOAL OF TECHNOLOGY							
		Enhancement Satisfaction		**Prevention Engagement**		**Compensation Assistance**		**Care Support & Organization**	
TIME PERIOD		**1990s**	**2010+**	**1990s**	**2010+**	**1990s**	**2010+**	**1990s**	**2010+**
LIFE DOMAIN	**Health & Self Esteem**	Self-care	Custom software	Home trainer	Health monitoring	Active alarms	Medication Reminder	Assistive Gadgets	Tele-medicine
	Housing & Daily Living	Remote control	Interactive controls	Thermostat	Smart ventilation	No barrier movement	Cleaning robots	Remote controls	Electronic keys
	Mobility & Transport	Timetables	Navigation tools	Handrails Sturdy grip	Automatic controls	Rollator walker	Smart walker	Powered lifting	Video links
	Communication & Governance	Ticket/fax machines	Multimedia connections	Noise control	Automatic messaging	Hearing aid	Cochlear implants	Vision aids	Text to speech
	Work & Leisure	Miniature camera	Digital camera	Safety equipment	Work simulators	Focused lighting	Virtual pets Robots	Computer games	Interactive games

the work force, are becoming a major target of technology. Recreational and stimulating leisure activities are crucial for the course of aging.

The four main goals of gerontechnology interventions are: Prevention and engagement - technology to delay or prevent age-associated physiological and behavioral changes that restrict human functioning; Compensation and assistance-technology that compensates for age-associated losses in strength and perceptual-motor functioning; and Care support and organization-use of technology by caregivers - often elderly themselves - of elderly persons who suffer physical or behavioral disabilities. Enhancement and satisfaction includes the innovative uses of technology; e.g., virtual reality, self adapting equipment to expand the range and depth of human activities with respect to comfort, vitality and productivity. This area represents the most opportunities for new research and development, emphasizing the expanding of human activities rather than compensating for defined limitations.

Examples of the rapid advances in technology over the past twenty years between the 1990s and 2010+ are shown in the cell entries taken from Bouma, Fozard and van Bronswijk[6]. The examples illustrate the importance of understanding cohort effects in gerontechnology interventions. Only one of the several entries in each cell of Tables 2 and 3 of that paper are included.

A person-environment transactional model

The transactional interplay between changes in individual aging (age effects) and secular changes in the environment (cohort effects) are illustrated (*Figure 1*).

The central concept of a transactional theory is that interactions between people and their environment should be considered as a system. Accordingly, the interface between person and environment is represented in the center of the diagram. The system output is represented in the rectangle on the right of the central person/environment diagram. Examples include performance errors, specific health outcomes, changes in emotions over time, etc. In human factors applications, 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. The contribution of the environment to the user interface has three components - social, built or manmade, and natural. The built and social components of the environment are the ones most often used to change user interfaces - the 'built' because it defines the displays and controls used to operate a technical product, the 'social' because expectations and experiences people have with products are powerful mediators of how a person uses the product[14]. The person in the system is shown receiving information from environment (receptors), internally processing the information (structures) and responding to it (effectors). Variations in the quality and type of information presented to the user as well the mode of interaction with the device, e.g., hand, foot, voice, can and do significantly influence the contribution of the person to the user interface and system output.

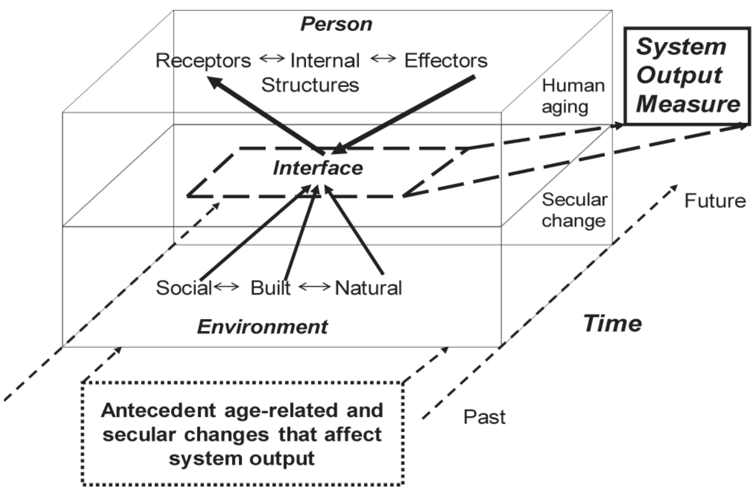

Figure 1. Person-environment transactional interface and its changes over time. Information from the environment is received by the person via receptors, e.g., visual or auditory, and responded to via effectors, e.g., voice, movement of limbs. The environmental information comes from the built or manmade 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 current person-environment interaction are shown at the bottom of the figure. The aging of a person born in one generation differs from that of person born in a different generation. Adapted from Fozard[13]

The arrows representing time in Figure 1 portray the dynamics of changes that may occur with aging and secular changes in the environment. Changes with time encompass the myriad of events that occur as a person ages: age effects. Time-related changes also provide the context for the multitude of environmental events that define successive birth cohorts: cohort effects. The following paragraphs identify some of the age and cohort effects that are important in gerontechnology. The complexity of the interactions between changing technology and the longer lives of people continuously increases over time[2,8,15,16]. Such changes are analyzed by ecological accounts of person-environment relationships, particularly as related to health and health promotion. Frankish[17] identifies several qualities of a healthful environment that affect human ageing including sustainability - energy use, renewable resource consumption, viability - air and water quality, contaminants and livability - housing, density, 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.

Age and cohort

Given the complexity of age and cohort effects it is useful to review the three procedures used to obtain scientific information on aging. Age and cohort information is contained in all three but the distinction between their effects may be difficult, limited in scope or even not possible[18]. The most common - called cross-sectional - is to simply gather the same information on people of different ages at one point in time. In such research, age related differences, if any, reflect both differences in age and differences in the environments in which the aging of members of members of a particular age group or cohort occurred. For some age changes the age differences are similar across time, e.g., the loss of accommodation in vision or the greater amount of light and contrast needed by older persons to perform visual tasks like reading[19]. Regardless of the cause of these age differences, the lighting interventions required to compensate for the average age associated difficulties are measurable and generally accurate.

In other situations the differences in the environment that occur over time can have a large impact on age differences. On the time dimension of Figure 1, imagine some calendar years and ages and consider a hypothetical study designed to compare the effects of an experimental dietary regimen on the strength of 20 and 60 year old men in Europe in 1970[20]. The early dietary experiences of the cohort of young men born in 1950 were different from those born in 1910, e.g., the availability of processed convenience Foods and no comparable fast food restaurants during 1910-1930. In addition, the men born in 1910 spent their childhood and part of their adult lives in two world wars with varying dietary experiences in peace and war. Any observed age differences in strength related to diet would reflect both age and cohort effects - the latter reflecting different dietary customs and differences in the varying dietary experiences of the 60 year old cohort. The common dietary options that could be shared between the 20 and 60 year olds in 1970 involved a group that was 40 years old at the time the 20 year olds were born.

Other limitations of information based on cross-sectional studies include questions about differences in the number, willingness to participate in research and availability of participants in younger and older cohorts - morbidity and mortality in members of old cohorts reduce the pool of potential participants in research. Of special importance for gerontechnology, the response to the introduction of a new technology by older and young persons varies with their experiences with using other technologies to accomplish a task. To deal with these problems researchers attempt to match or control for differences in the abilities or health of young and old participants or to use training to a fixed performance criteria to account for initial age differences.

The second most common technique, called longitudinal, involves making repeated observations on the same people over time to describe age-related changes in performance or functioning. In closed-panel longitudinal studies, members of one or more age cohorts are followed as they age, starting at the same point in time. In open panel studies persons of a particular age but representing different cohorts are followed. These studies have been useful in studies of child and adolescent development[21]. In closed panel studies, the aging effects observed reflect changes with age as well as differences associated with the changes in the environment in which aging occurs: aging from 20 to 30 starting in 1950 is different from aging from 20-30 starting in 1910. In one open panel longitudinal study, the Baltimore Longitudinal Study of Aging[20], new participants from successive age cohorts on a waiting list are added to the existing participant group so that a new 60 year old participant's data are combined with those of existing 60 year-old participants. The goal is to maintain a continuous infusion of new participants so that there is a fixed number of participants in each age cohort with a designated duration of participation (minimum of 12 years) as the study continues.

The third and least common technique because of its resource-intensive character - called cross-sequential - involves combining features of cross-sectional and longitudinal studies of aging to address some weaknesses in longitudinal studies. The changes with age of a cohort studied longitudinally for 10 years can be compared to members of the same cohort who are measured once at the end of 10 year observation period. If there are no differences then it can be inferred that the effects of being studied for 10 years do not influence the reported age-related changes. In multiple cohort longitudinal studies, measuring age differences between cross-sectional comparisons of cohorts differing by 10 years in age and those of age peers studied for ten years over the same period provides information about aging attributable to differences in cohorts born at different times. The best-known study that uses this approach is the Seattle Longitudinal Aging Study[22]. This study evaluates age related changes in cognitive functioning over 7-year intervals in different age cohorts. Adding one time assessments of age differences provides information about practice effects and generational differences in education.

In addition to these three classic strategies, experimental research contrasting younger and old ages is a classic means particularly in cognitive aging research. Although experimental work is also prone to cohort influences, this design is generally regarded as able to target more fundamental processes related to aging, while cohort influences are typically regarded as limited..

The optimal source of information about age and cohort effects in gerontechnology would come from open panel longitudinal or cross-sequential studies. New tasks may be experienced differently by younger and older cohorts; changes in the way existing tasks are performed mean new learning by members of young cohorts and adaptation to the new tasks by members of older cohorts[23]. At present there is little research using these approaches. With respect to aging, when there is congruence in results of cross-sectional and longitudinal research findings[24], it is reasonable to expect that the results will not change radically over successive generations--at least at time of writing. Because of this congruence between longitudinal and cross-sectional findings, here is now a rather robust knowledge related to human aging--sensory and perceptual functioning, physical functioning and the development of chronic diseases.

Expanding the transactional model

Differentiations at the level of age

Four groups of age effects are of particular interest in gerontechnology: (i) sensory and motor functioning; (ii) cognitive performance; (iii) personality and self; and (iv) motivation and emotion. In sensory and motor functioning the loss of visual accommodation begins in infancy and is universal. Longitudinal studies of multiple age cohorts reveal a decline in visual acuity in healthy adults particularly over age 70 that is progressive and virtually ubiquitous[25,26], a decline also associated with poorer contrast sensitivity[27]. Similar changes are observed in light sensitivity and dark adaptation[19]. Severe vision loss, prototypically due to age-related macular degeneration, has been found in 20% of those 65 years and older and 25% of those 75 years and older[28,29]. The development of moderate-to-severe hearing loss, more prominent in men, has been replicated in two major American longitudinal studies[30,31,32] and others[28]. Age-related vision and hearing loss are functional losses of high saliency in the everyday lives of older adults; they are important markers of awareness of age-related change[33]. The major gerontechnological interventions for these areas are compensatory rather than preventive.

Motor impairment, related functional limitations and problems with gait and balance have as well found to be closely connected with calendar age and tend to reveal at least a threefold magnitude in those over 85 years of age as compared to those with a mean age of 70 years[34]. For example, walking problems are reported by about 10% in young-old individuals, but 35% in those beyond 85 years. Unlike sensory perceptual processes, many age-associated limitations in personal mobility can be modified by exercise and strength training, both examples of preventive interventions[13]. An important issue in this area has been the common cause hypothesis which assumes that a common age-related central nervous decline process lies behind a major portion of what we see in terms of sensory and motor performance decline, which goes hand in hand with cognitive decline. Therefore, age-related trajectories in sensory and motor function are far from reflecting only disease processes operating at the periphery of organs, but a general age-related decline dynamic operating at the brain at large. Kearns and colleagues for example have shown that variability or tortuosity in movement paths of everyday movement paths increases in persons with impaired cognition or dementia, both of which concerning loss of spatial orientation[35,36].

The relation between cognitive performance and calendar age is more complex. On the one hand, there are many cognitive abilities showing a clear picture of age-related decline such as information processing speed, working memory performance, episodic memory, executive control, attention, and dual-task performance[37]. On the other hand, it is important to note that such age-related decline in many cases is limited and rarely affects a range of mental capabilities in simultaneous manner[22]. At the same time, important areas of cognitive performance such as vocabulary, life experience and wisdom related knowledge, expertise and geographical orientation, remain rather stable until very late in life. The amount of the decline varies depending on the nature of the task, and a number of moderating factors, the most important of which are prior and current health, sensory abilities, and education level. The age associated declines in cognitive performance are also seen in varying degrees in young adults with traumatic brain injury. The use of machine-mediated systems for timely prompting related to following directions taking medicines, and keeping appointments being developed for rehabilitation of military veterans should improve possibilities for compensatory interventions for older persons[38,39]. Overall, it has become increasingly clear in this area that calendar age is not an explanatory variable but rather a marker for a continuing change in multiple physiological systems that influence both laboratory-based and everyday cognitive tasks[40,41]. The most common interventions are task redesign and training, both compensatory interventions. Excellent examples of both approaches are provided by Fisk, Rogers, Charness, Czaja and Sharit[42].

The relation between personality and self and calendar age is again a multi-faceted issue and far from being a 'decline story', even in the light of pronounced sensory, physical functioning and cognitive impairment in later life. Self-ratings of personality traits as well as those by others show that traits such as extraversion, neuroticism, and openness to experience remain fairly stable over the adult life course, although longitudinal data also indicate that traits evaluated as more positive (e.g., openness to experience) as well as those operating more at the negative end (such as neuroticism) show some decline[43,44]. It can be assumed that greater openness to experience is associated with greater acceptance to new technology in older persons. Another important issue is control beliefs. Age effects in self-rating of personal vs. external factors in locus of control[45] are slight. Internal control beliefs remain stable, while external control beliefs increase[46]. The fundamental potential of human resilience, i.e. the capacity of efficient restoration in highly adverse circumstances[47] persists into very old age and the widely confirmed well-being paradox underscores that the correlation between calendar age and well-being is rather low.

The relations between motivation and emotion and calendar age reflect age effects and probably cohort effects as well. Socio-emotional selectivity theory assumes that intimacy needs and familiar contexts are increasing as we age, while needs for new knowledge, new experiences, and unknown contexts is on the fall. The theory also posits that the motivational force behind is reduced future time perspective, which typically comes with old age, but may also happen earlier in life, for instance due to serious illness. Wahl, Iwarsson, and Oswald[16] make a similar argument in their view that processes of agency - including the full range of goal-directed behaviors related to environment, such as control over the physical environment - is on the decrease as we age, whereas the need for belonging related processes increases. There are nevertheless also important views assuming that even if this is the case, a fundamental human striving toward primary control is on the developmental agenda from birth to death and that a lot of human investment (including technology) has such a fundamental human need in its background[49]. In addition, cross-sectional as well as longitudinal data support the notion that the experience of positive affect does not show major decline and that negative affect is on the decrease as we age[50].

Differentiations at cohort level

We consider three groups of cohort effects with implications for gerontechnology. Unspecific cohort effects include the continuous increase of longevity across successive birth cohorts[51], the continuing increase in educational input early in life across cohorts, the increase in singularization in midlife and old age across following cohorts, for instance due to increasing divorce rates, and a general tendency at least in Western societies toward individualization at large. Such cohort effects are called unspecific because they come with a huge range of potential impacts on the life domains addressed by gerontechnology. For example, the constant increase in life expectancy will simply increase the potential number of gerontechnology users, but also challenge gerontechnology to create appliances and services at large as an increasingly important means to support and stimulate the 'long aging'.

Specific cohort effects with more direct implications for gerontechnology include: the overall trend toward improved health and functioning, augmented cognitive functioning and a generally growing positive view of aging, and a heightened view of forthcoming cohorts of maintaining self-efficacy in old and very old age as compared to previous cohorts[16,52]. Such cohort effects directly impact on technology use and need at various levels. For example, the increase in health and functioning of future cohorts of older adults will reduce to some extent the need for compensatory technology solutions. At the same time, heightened overall cognitive functioning and possible the longer maintenance of cognitive function onto very old age in future cohorts of older adults may allow the application of more complex user interfaces of various technology solutions, particularly information and communication technology, and thereby enhance the potential of such technology for old and very old individuals in the future.

Direct technology-related cohort effects have the strongest implications for gerontechnology use and need. Knowledge of and experience with information and communication technology lead to increasingly positive attitudes to use such technology in future cohorts of older adults[53]. These observations have resulted in research on technology acceptance both in work settings in which technology use is required as well as in situations where it is optional. Sackmann and Waymann[4] classified successive birth cohorts ranging from the 1930s to the 1970s according to the introduction of various major household technological products ranging from the radio and telephone to television, automatic clothes washers and driers, home computers, and other advances. They documented how successive cohorts of people had their first interactions with various technological products at strikingly different ages. More sophisticated analyses of differences in cohort-technology interactions were reported by Mollenkopf, Marcellini, Ruoppila, Széman and Tacken[54] in the area of out-of-home mobility, underlining that the expectation that technology (such as car driving assistance systems) should strongly support older mobile adult in the future. In a seminal study, Docampo Rama et al.[3] used simulations of two styles of user interface (electromechanical interfaces before the 1980s and software style interfaces later) and compared the speed and accuracy of their use by young adult participants whose early experience (defined as 10-20 years of age) with the user interface as opposed to three groups of older adults representing cohorts whose early experience was with the electromechanical interface. In addition to the two types of device, levels of difficulty of the task were manipulated so that age related differences in performance and early experience effects could be distinguished. Age related performance was poorer as task difficulty increased, but all cohort groups improved with repeated trials, both findings in keeping with other literature. With task difficulty controlled, the participants whose early experience was with software interfaces performed better on that style device than any of the cohorts whose early experience was with the electromechanical style interface. The research results convincingly indicate that the interaction with different cohorts may augment or reduce observed age effects in technology use. At the same time, we expect in the light of such findings that focusing the technology and aging interface in historical, and thus cohort related, terms is able to add a so far mostly neglected facet to the ongoing cohort discussion in gerontology and may actually point to a sphere so far underrated in gerontology in its importance for successful aging[52,16].

A framework for gerontechnology

Figure 2 brings together the five domains of gerontechnology applications named in Table 1 with the age and cohort effects discussed in the previous section. The overall message is that both age and cohort effects exert their influence simultaneously on these domains, resulting in variations in technology supported quality of life over historical time (*Figure 2*). Indeed, the span of years that is used to define an age cohort as well as the placement of those years in historical time can profoundly affect how technology can be used to support human activity. The distinction made by Tapscott[23] between 'digital natives' - young persons born after access to the Internet was widely available - as opposed to 'digital immigrants' is an example. He argues and provides some evidence from interviews that digital natives acquire and use information and carry on social relationships differently than digital immigrants. The complex age and cohort effects described above suggest that his distinction is an over-simplification.

Table 1 has shown the roles of gerontechnology to compensate for various age-related deficits such as a generally increasing rate of multimorbidity (health and self-esteem; e.g., telemedicine, alarm systems), reduced everyday competence (housing and daily living; e.g., smart ADL and IADL support), increased mobility and transfer problems (mobility and transport; e.g., intelligent car systems), hearing impairment (communication and governance; e.g., hearing aids) and reduced speed in cognitive processing with relevance for work environments (work and leisure; e.g., smart work environments reducing the cognitive load of production processes). Figure 2 also highlights the fact that aging comes with stability or even increase in some of the more pragmatic cognitive domains as well as personality. Here, gerontechnology's potential in terms of life enhancement and satisfaction can normatively (i.e. regarding the majority of old and very old adults) rely on continuity in key quality of life domains and provide various tools for optimization. In a sense, this is not 'geron'-technology operating here, but technology is serving and enriching individuals along the full adult age range including old and very old age. It seems important in terms of the image of aging underlying gerontechnology and its potentially age stigmatizing role that in many cases compensating/care and enhancement/satisfaction goals are operating hand in hand in gerontechnology appliances. For example, in the area of communication and governance, the compensation of reduced hearing may be enriched at the same time with an internet-based education or social networking program able to aid to further development of an aging person's personality and self (e.g., his or her openness for experience). Regarding health and self-esteem, to take another example, it is of importance that technology such as e-health appliances and internet-based prevention and engagement programs may be able to add to the maintenance of personality and self, for example in terms of fostering psychological resilience in regard to forthcoming health challenges. Going further, observed life-span trajectories in motivation and emotion, i.e. becoming more internalized and spirituality oriented, have nothing to do with a deficit perspective of aging. On the contrary, such age-related motivational shifts are highly adaptive in terms of accepting decreasing biological functioning and gerontechnology may be able to support such processes at least to some extent. For instance, simply using technology such as mobility and communication devices may elicit feelings of being alive and vital even in the situation of dramatic health and function impairment. Technology allowing one to stay in one's home environment as long as possible or securing communication with close relatives and friends in an as naturally as possible way also strongly aids to important life goals in very old persons. Robot pets may take over some of such functions in demented older adults and enrich their needs for social relatedness and intimacy in daily life.

Figure 2 also displays various cohort effects that are also shaping age X gerontechnology interactions over time. Increasing longevity will provide a huge challenge for gerontechnology. For example, a growing share of populations will experience a rather long "fourth age" with all the health and care, but also existential tasks coming with extreme old age. It may become highly critical that gerontechnology may still more intensively serve the personality and self as well as fundamental motivational tendencies of aging human beings in order help them cope with multiple losses and an exerting long life period in the nearness of death. Indeed, such a task may in the longer run become as important as the range of compensating and care oriented gerontechnology potentials available for those being very old. Cohort trends such as the better education of forthcoming older adults, an increase in self-efficacy expectations and more positive attitudes toward technology use at large may also add to this increasing role of gerontechnology as a means to foster enhancement and satisfaction and prevention and engagement and possibly no longer not so much its compensation and assistance or care oriented function. Could it be that we will see in the not too far future old individuals who 'love' their robots and not see them simply as compensatory tools? In terms of a widely acknowledged meta-model of human development, the model of selective compensation and optimization (SOC[55]), we expect that compensation will continue to be an important function of gerontechnology for aging people. However, the optimization related potential of technology may indeed take over in the not too far future. Think of technology able to enrich cognitive engagement and knowledge as well social interchange, but also technology offering inspiring virtual environments to enjoy by future elders[2,16].

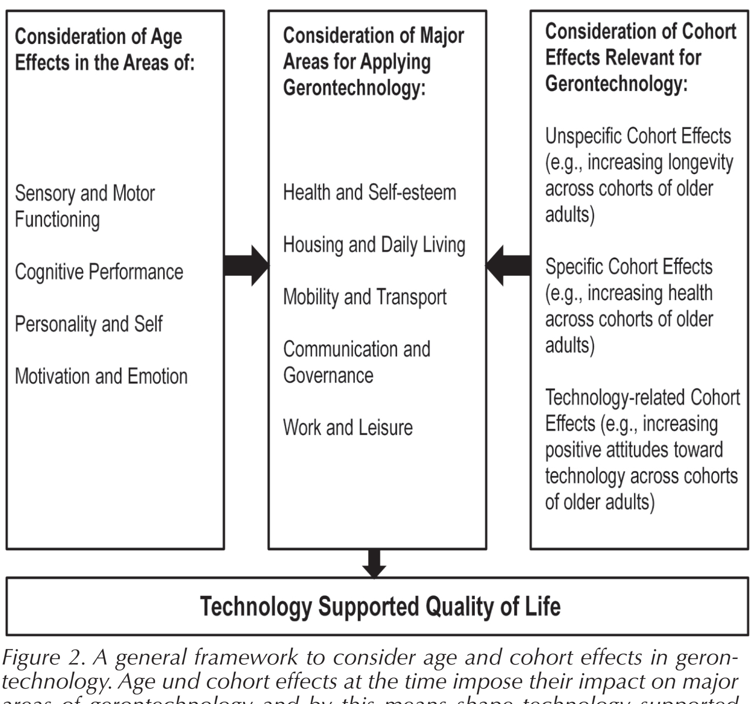

Figure 2. A general framework to consider age and cohort effects in gerontechnology. Age und cohort effects at the time impose their impact on major areas of gerontechnology and by this means shape technology supported quality of life of older adults. A taxonomy of age and cohort effects is suggested to better understand such impact

Conclusions and recommendations

Sometimes technology develops faster than the needs or abilities of persons to use it: individual lag; at other times technology lags behind human needs and interests: social structural lag[56,57,58]. Lawton's thinking is built on Rileys' notion of structural lag[59], which strongly relies on the consideration of age and cohort effects in ageing societies. Age-related illness, cognitive and perceptual-motor declines and negative attitudes toward old age are the major ingredients of individual lag. The role of gerontechnology in individual lag is predominantly compensatory, e.g., the development of products and user interfaces that facilitate the use of the products by older persons. The core ingredient of social structural lag results from a social structure that emphasizes education for the young, work for the young and middle-aged adult, and leisure for the old. Current improvements in the longevity and health of older cohorts create demands on the physical and built environment to better support opportunities for leisure, education, creative activities and work for older persons. Because cohort effects are important in social structural lag, the major roles of gerontechnology include enhancement and optimization, the complement of compensation. One major lesson resulting from the distinction between individual and social lag is that examples of individual lag will highly likely persist as successive technology generations interact with different cohorts of ageing people. While the role of early experience is an important contributor to the individual lag, the usefulness of task design and training interventions will be highly specific to particular applications as suggested by Rogers and Fisk[53]. Overall, the future of social lag will largely depend on society policy for older adults and the wide enrichment of opportunity structures to unfold the potential of older adults even in the situation of increasing vulnerability and biological impairment, not the least by means of technology use and appliances.

A central argument of the present paper is that gerontechnology put equal emphasis on both compensation and optimization. In a sense, this reflects nothing else than the central goal of gerontechnology, i.e. to achieve an optimal balance between the preferences, interests and needs of consumers of technology - consumer pull for short - and the rapid developments of scientific engineering knowledge that provide the bases for developing and marketing new technological products and services - technology push[60]. Technology push may result in the development and marketing of technology inspired products that contain novel combinations of functions, e.g., cellular telephones that may also be used for playing games or as a camera. The dynamics of consumer pull and technology push can change in complex ways over time, frequently affecting persons of different ages in different ways. For example, the first experience of using a menu-driven control device for a new electronic game for a child is very different from that of an older adult who may have lived most of his or her life without the product or in the case of an existing product, with an earlier configuration of displays and controls for interacting with it, for example, a film vs. digital camera. The effects of technology push are not confined to new technology-related products. Changing control devices require users to adapt to changing technology in familiar products continuously over the life span. For example, a contemporary older adult may he accustomed to an earlier generation of electromechanical controls that accomplished the same purpose as the new, menu-driven controls. Many older adults at the turn of the 21st century may have adapted to several control devices for the telephone - a hand crank for creating a signal of rings, rotary telephones, touch-tone telephones, and now the menu-driven controls combining visual presentation of calling options and a variety of button controls some of which have multiple functions. Another example is provided by the clothes washing machine. An older person in the 21st century may have experienced the evolution of controls - called user interfaces by designers and engineers - ranging from a manually started gas driven machine to a contemporary electric powered machine operated by a complex array of digital electronic controls. At the same point in time, a young, first time user of washing machines might only recognize the contemporary machine as the prototype washing machine. The lessons from these examples are that older adults of any age can expect secular changes in technology both with respect to adapting to new products and novel ways of using familiar products and that there will always be young adults or children who have never experienced older user interfaces. The foregoing examples emphasize the importance of changes in user interfaces as a source of difficulty in using products. The examples do not negate the central importance of good ergonomic principles in the design of interfaces for users of any age or level of experience[14]. Bouma's[60] discussion of 'consumer pull' argued that consumer input should be involved in the dispersal and distribution of technology, not simply its development[61]. Recent developments in work related technology shows that Bouma's concept applies here as well. Experience with integrating robots with aging Japanese workers and the use of a combination of younger and older workers to redesign an automobile assembly line illustrate the value of involving the user in the use and acceptance of new technology[62]. Such person oriented interventions help overcome age associated decreases in the acceptance of new technology[63].

To translate such insights to the research level, empirical studies such as the one by Docampo Rama et al.[3] are critical for the understanding of what gerontechnology has to offer to human development today and onto the future. The important issue of such studies is that they extend beyond the sole consideration of age effects, to include the interplay of age effects and cohort. Most of the major longitudinal or cross-sequential studies all over the world[64] have not incorporated cohort related environmental and technological into their designs. To do so would provide an opportunity to provide insights into a wider range of constructs from biology, health, psychology and sociology.

In conclusion, it is highly important to enlarge the focus of empirical gerontechnology research on cognitive abilities with the areas of personality and self, as well as motivation and emotion. As we have argued, such research will not only serve an important future trend inherent in technology use and need toward enhancement and optimization, but also serves a view of aging as not being an oxymoron for developmental growth and productivity. Therefore, gerontechnology may also increasingly serve gerontology at large in the future. Herman Bouma's research success, conceptual creativity as well as his constant emphasis on the crucial role of end user involvement gives us an important orientation to accomplish this task in the time to come.

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