

Healthy ageing supported by technology – a cross-disciplinary research challenge

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Abstract

During the last decade, the challenges of an ageing society became focus for extensive scientific, public and political discussions. From discussions in scientific fora within each discipline, there is now a shift towards cross-disciplinary scientific approaches. The aim of this article is therefore, to collect and describe different scientific viewpoints in this regard and to point out research gaps to be addressed in the future. The article is based on a number of review articles and keynote lectures given by the author, and complemented with informal interviews of experts from different scientific fields engaged in the field of technology and ageing. Results show that research has emerged from being technology-focussed to scenario-based taking different scientific perspectives into account. However, the biggest challenge still is to accommodate the need for a holistic integrated service which means to provide personalised services and adapt technology and content to individual needs of different stakeholders. Further, cross-disciplinary research is needed that relates informatics and technology to different stages of the aging process and that evaluates the effects of proposed technical solutions.

Keywords: *Ageing, consumer health information, independent living, medical informatics, technology*

1. Introduction

The phenomenon of an aging society is frequently raised in scientific, public and political discussions in the developed world, and future needs for health and social care are highly influenced by demographic, economic and societal developments.

1.1. Demographic development

Demographic data from the United States indicate that the number of persons aged 65 years or older will raise from 38.9 million in 2008 (= 12.8% of the U.S. population) to 72.1 million older persons (= 19% of the population) by 2030 [1]. European figures predict an increase in the share of people aged 65 years or above in the total population from 17.1 to 30.0% and the

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absolute number is projected to rise from 84.6 million in 2008 to 151.5 million in 2060 [2]. Similarly, the number of people aged 80 years or above is projected to almost triple from 21.8 million in 2008 to 61.4 million in 2060 [2]. Also, the old age dependency ratio is expected to increase substantially in Europe from its current levels of 25.4–53.5% in 2060, whereas in 2008 in the EU27 there are four persons of working age (15–64 years old) for every person aged 65 years or over; in 2060 the ratio is expected to be 2 to 1 [2].

1.2. Economic development

Higher standards of living will lead to greater expectations of the quality of healthcare systems. At the same time, public health services have to cope with financial resource constraints and shortage of skilled labour [3]. Globally in 2006, expenditure on health was about 8.7% of the gross domestic product, with the highest level in the Americas at 12.8% and the lowest in the South-East Asia Region at 3.4%. The share of government in health spending varies from 76% in Europe to 34% in South-East Asia [4]. The largest share of the overall per capita costs, for example in Germany, is attributed to the very elderly people [5] which is partly due to co-morbidity. According to the law in most countries, the provision of health care and social services shall be adjusted to meet the needs of the citizens. What we are going to face, however, is a situation where citizens will ask for more health and social care than needed. Namely, demand is not necessarily the same as need but will shape a new citizen-driven market depending on the economical development.

1.3. Societal development

The future needs for health and social care will also be influenced by social factors. The citizens' valuations will, independent of the economical development, lead towards a more individualistic approach of how health and social care should be provided. It is almost certain that an increasing number of older people live alone, and increased mobility in society results in families/relatives distributed over large geographical areas. The challenge facing all western societies is twofold: ensuring that present and future older people can look forward to improvements in their function and care, and countering the decreasing societal commitment to the older people, who are often perceived as a 'burden' [6].

Today, social care is very much supported by relatives whom in the future will be able to take part in the care process from a distance. Here extended use of modern ICT has the potential to help to bridge distances, to provide social inclusion without necessarily raising costs and to enhance quality of care using relatives at a distance as quality controllers of the care process.

Effective delivery of healthcare will be more dependent on different technological solutions supporting the decentralisation of healthcare, higher patient involvement and increased societal demands. Such technologies need to be developed, implemented and studied in their contextual settings.

In the light of demographic change and ageing, different initiatives to prepare for meeting the challenges of an increased elderly population in an economically sustainable and effective way are proposed. The European Commission, for example, has adopted a European Action Plan for 'Ageing Well in the Information Society' in 2007 [7] and launched the Ambient Assisted Living Joint Programme, a funding activity to enhance the quality of life of older people and strengthen the industrial base in Europe through the use of Information and Communication Technologies (ICT).

The concept of Ambient Assisted Living in this context is understood as

- ‘to extend the time people can live in their preferred environment by increasing their autonomy, self-confidence and mobility,
- to support maintaining health and functional capability of the elderly individuals,
- to promote a better and healthier lifestyle for individuals at risk,
- to enhance the security, to prevent social isolation and to support maintaining the multifunctional network around the individual,
- to support carers, families and care organisations, and
- to increase the efficiency and productivity of used resources in the ageing societies’ [8].

This requires a cross-disciplinary approach in order to design appropriate solutions to support new care processes, to address the medical and social needs of an ageing society and to evaluate the effects of new technological solutions and process redesign. The aim of this article is therefore to collect and describe the viewpoints from different scientific disciplines in this regard and to point out research gaps to be addressed in the future.

2. Methods

The article is based on the scientific literature that was studied by the author during the past 5 years on the topic of ageing and technology. Parts of the material have been published in form of systematic reviews [9,10] or were presented in form of keynote lectures at international conferences [11–13]. Discussions with researchers from other scientific domains than the author’s own domain, which is health informatics, have contributed to setting the material into a broader context, to analyse the development of the field and to identify knowledge gaps for future research.

3. Medical implications and redesign of healthcare processes

We are reaching higher age in better health. However, the prevalence of diseases in the elderly population has tended to increase over time [14]. This is partly due to improvements regarding early diagnosis and treatment leading to a longer period of morbidity, but with an improved functional status [15]. Although prevalence has increased, mortality is being postponed and it seems that death is being delayed because people are reaching old age in better health and not because the rate of increase of mortality with age is being slowed [16].

The rise in prevalence has been reported for several chronic conditions such as cardiovascular diseases, pulmonary diseases, diabetes and diseases of the musculoskeletal system, such as arthritis. In very elderly persons, a combination of these conditions is often present. For example the Berlin Aging Study (BASE) has shown that 88% of the persons aged above 70 years suffer from five or more somatic diseases [17]. This situation increases the demand for personalised medicine, offering methods for more individualised measurement, analysis, treatment and prevention. Older people suffering from multiple conditions also need proactive management from a variety of different health and social care professionals, following agreed protocols that can handle co-morbidity, shared care plans and personal life goals [18].

This, of course, requires interoperable information structures and has an impact on how health and social care will be delivered. The paradigm shift regarding care models does not only include a shift towards integrated care models from a care professional’s point of view. It also includes a shift towards partnership models, involving the family carer as expert [19] or the patient as expert thereby also putting higher responsibility on patients and family carers.

This situation will lead to a combination of formal and informal care giving, self care and lifestyle management, both locally and at a distance, supported by technology and controlled by the patient/citizen.

4. Needs and expectations of an ageing population

Population ageing is characterised by changes in the proportion of different age groups. In the current population, we will see a decrease in the proportion of young people, (<20) followed by an increase in the working age group (20–64), leading to an immense increase in the oldest age group (>64) [20]. Due to higher life expectancy and healthier ageing, this oldest age group will consist of younger retired people, the so-called sandwich generation (64–84), and very elderly people or ‘oldest-old’ (>84) [21]. The last two categories are also known as ‘third age’ and ‘fourth age’. In reality, these age categories have no fixed limits but are the categories that are currently available to identify, define and, more recently, transform the process of contemporary ageing [22].

As the oldest-old are expected to make up an increasing proportion of the number of retired people, the sandwich generation will play a pivotal role as informal caregivers [23]. So, the ageing society is formed by a multi-actor network consisting of the oldest-old, younger retired persons, their family members and care professionals. This also means that older people are certainly not a homogenous group.

They may belong to the oldest-old or younger retired people, they may suffer from functional or mental disabilities or not and, in general, their needs and goals of life are not fundamentally different from those of any other adults. They want to remain independent as long as possible and to keep control over their lives once outside help is needed, thereby maintaining the feeling of independence [24].

With older adults living longer and healthier lives than ever before, the concepts of active, successful and healthy ageing arose which in practice means adopting healthy life styles, working longer and remaining active after retirement [23]. Apart from a good medical condition, throughout life, mental and physical health is affected by the presence, absence and quality of ties to other people [25]. Older people who volunteer with children, for example, burn 20% more calories per week, experience fewer falls and rely less on canes [26] and 56% of baby boomers rate civic engagement to be important when retired [27]. Intergenerational programmes form therefore an important measure to support social connectedness. Another study analysing factors associated to quality of life in active older people among a study population of 120 active older people found that the functional status had no influence on the quality of life [28]. In contrast, psychological factors, as assessed by the Geriatric Depression Scale, and socio-demographic characteristics, such as marital status, income and leisure activities, had an impact on quality of life [28].

In contrast to the active ageing movements, which also might put societal pressure on the individual, the Theory of Gerotranscendence [29] describes a possible natural progression towards maturation and wisdom where Gerotranscendence is regarded as the final stage. This theory describes individuals with a decreased interest in superfluous social interaction. They will become less self-occupied and at the same time more selective in the choice of social and other activities where positive solitude becomes more important.

4.1. Use of technology among older people

A common prejudice by care professionals is that older people are unable or not willing to use new technology. Eighty percent of Europe’s home care decision makers, for example, believe

that the acceptance of ICT-based services among older adults is very low [30]. However, the 2005 Eurostat ICT survey in all 25 member states revealed that 24.9% of the private individuals in age group 55–74 use the Internet at least once a week [31]. A follow-up of the survey in 2007 in by then 27 member states showed that 31% of men and 19% of women in age group 55–74 use the Internet at least once a week [2] and a recently published study shows that two third in the age group 55–64 use the Internet in Sweden [32]. We know that the future generation of older people is more educated, more demanding and has experienced the fastest technology development ever. More than 80% of baby boomers fully expect scientific and technological advances to improve their lives as they age [33].

Future older people are predicted to be more responsive to technology and technology is able to meet the demands of managing age-related diseases and disabilities. However, what kind of technology will the demanding generation of future older people accept? Products for disabled users are often thought to be used for older users, too. While the physical needs may be similar, the older person, acquiring a disability slowly over time, often does not show the same level of awareness or acceptance that usually accompanies disabilities at birth or by accident [34]. Instead other family members or informal carers are often the first to realise the need for specific technologies or aids.

This accentuates the increasing role of family members, relatives and informal carers not only as future care resources but also as target costumers for new product design.

4.2. Gender aspects

With rising age, women make up an increasing share of the population. Real-user involvement is also important when it comes to the patient groups in focus. We observe a gender imbalance as, for example, most of the older people requiring homecare services are women. This is due to demographic facts of greater longevity of women than men, which is today well documented [35]. We can thus talk of a ‘feminisation’ of later life. This has also been identified as the health-survival paradox, as women tend to seek more health care during their lives, but never the less live longer than men who seem to be healthier but die younger [36]. This fact also makes women more sensitive and vulnerable to unjust priorities in health care. Several studies have noticed that age and gender might in some cases interact negatively in health care practice [37,38]. Further, patients with mental disorders are often regarded as gender neutral individuals, although recent studies have shown gender-related differences in relation to mental disorders, which need to be addressed [39,40].

Inclusion of a gender perspective is mandatory for research, not least in eHealth, as, in addition, the majority of staff, especially in home and elderly care, consists of women. This goes back to the traditional gender-based division of work, in which women were responsible for and referred to the private sphere and its related care tasks [41,42]. On the other hand, the majority of IT systems are still designed and developed by men. Research on gender differences regarding the use of technology is scarce [9] but previous research showed that older women consider themselves to be technophobes [43] and that social care staff, with a majority being female, define themselves as technologically unskilled although they use a variety of technologies in their work [44]. A Japanese study showed that older women are more frequent users of household appliances but are less frequent users of IT and digital devices than older men [45]. With regard to searching the Internet, however, older women were found to be more likely searching the Internet for health information than older men [46], especially when searching was not related to a clinical visit [47]. In China, women in general constitute a higher proportion of all Internet users than men; however, the total number of Internet users over 50 years of age is far lower than in other countries [48].

The oldest-old will be the pre-dominant patient group requiring health and medical care and/or social care. However, as stated in Section 3, people are reaching old age in better health and not all oldest-old will require help with their everyday needs. According to the U.S. national long-term care survey, for instance, only about half of Americans aged 85 or older are dependent on others to perform personal care or instrumental activities of daily living [23]. Moreover, the future oldest-old, having benefited from higher education and better working and living conditions and being more wealthy, may prefer to pay for formal care rather than rely on family support [21].

The younger retired people are the active retired generation and will be the main contributors to long-term care of the oldest people by providing informal care to their parents. However, oldest-old support ratios are expected to decrease. This will lead to a decrease of informal carers and may lead to an increase in formal care services [21] and also to an increase in the use of technology. Technology that will be targeted to different user groups such as older persons (healthy or unhealthy) at different stages of the ageing process, relatives (who may or may not be elderly and/or informal carers) and health and social care staff (who may or may not be elderly). For older persons, it is important that technology compensates for age-related declines, supports the older person's independence and lets him/her keep control over his/her life. For relatives, access to information is key. This gives far-away living relatives a feeling of security and trust and ensures participation, education and activity of family carers. Regarding health and social care professionals, technology needs to support their clinical work processes regarding information, communication and coordination needs.

5. Emerging technologies and their context of use

In Section 4, three different elderly target groups for AAL technologies were described: health and social care staff (who may or may not be older people), relatives (who may or may not be informal carers) and older citizens/patients at different stages of age-related declines. In this section, different technologies will be related to different stages of the ageing process with the aim to support the different target user groups in their activities. In this regard, the ageing process is based on three different stages, namely, 'independent living', 'assisted living' and 'dependent living' where the first two stages are considered to be the stages where technology can be applied in a meaningful way. Different technical solutions may include 'technologies for life-style management', 'technologies for early detection of disease', 'technologies for assistance in daily living' and 'technologies for disease-related specific management'.

5.1. Technologies for independent living

Technologies for life-style management often consist of so-called health-enabling technologies that are information and communication technologies for creating sustainable conditions for self-sufficient and self-determined lifestyles [49]. Based on sensor-technology, they can, for example, be used to measure physical activity and in combination with computer-based dietary strategies and training programs be used for overweight and obesity prevention [50]. In order to achieve the necessary behavioural change, health-enabling technologies use the individual feedback of analysed data to motivate people to change their lifestyles [13].

Health-related sensor technologies, stationary or mobile, can also be used for early detection of relevant medical conditions and parameters. Measurement of blood pressure, heart rate and weight have since long time been established medical practice for detection of cardiovascular diseases and also parameters for asthma or chronic obstructive pulmonary

disease (COPD) such as peak flow, breath rate and blood oxygen saturation are measured at home already. The same is valid for ambulatory measurement of blood-glucose regarding diabetes. The use of biomarkers for early diagnosis of myocardial infarction, respiratory infection or dementia, however, are still only used in hospital settings or at a research state without regular tests so far [13]. For diseases of the musculoskeletal system, gait patterns [51] and postural stability [52] are among the parameters that are used for diagnosis of, for example, individual fall risk [53,54] and may be assessed unobtrusively during everyday activities [55].

Still most sensors are applied in a stand-alone fashion and assembling different sensors in the environment [56] or as body area networks [57] and then combining those are fields of active research. Further, the pervasive combination of real-time sensor data [18,58,59] and their integration with e-services, clinical information systems and personal health records (PHRs) [60–62] address key areas for personalised healthcare [63].

5.2. Technologies for assisted living

Assistive technologies have enabled independence for people with cognitive and/or functional disabilities or impairments for a long time. Examples include electronic wheelchairs, visual and hearing aids and cognitive support systems. In general, assistive technologies enable persons with disabilities to perform tasks they were formerly unable or had great difficulties to accomplish. In the form of ‘smart homes’, technology has also become a part of the residential infrastructure. Beyond issues of comfort and leisure, smart homes are mainly intended to monitor older people with motor, visual, auditory or cognitive disabilities [64,65]. Smart home technologies consist mainly of safety technologies such as fall detection, mobility aids, stove use detectors, smoke and temperature alarms, door locks and automatic lighting but are increasingly connected also to health and wellness technologies such as health enabling and telehealth solutions as well as cognitive support systems such as reminders for upcoming appointments or events. A recent review about smart home technologies can be found in [66]. According to Demiris *et al.* [67] it is important to design solutions that are transparent to the elder person, that minimise changes to the environment and that deploy a sensor network as soon as possible in order to be able to add more functionality to that infrastructure. To put sensors or devices on the person should be avoided as much as possible.

In the area of physical and cognitive rehabilitation, the field of ‘serious gaming’ or ‘exergaming’ (= games linked to exercise) has emerged as a new research area to study the effects of computer-based entertainment as a form of training to improve health.

To assist older people with mobility declines, research in the areas of biomedical and assistive robotics is directed towards the creation of mobile, humanoid robots [68–70].

Information technology for dementia patients is a rather unexplored field that still seems to be at an initial stage of development [71]. Some European projects target this problem using broad-based intervention techniques of intellectual and social stimulation by applying, for example, social networking techniques [72]. Other groups work with the development of new, tangible user interfaces that allow for interaction with digital information through physical environments [72].

5.3. Support for relatives, family carers and health and social care professionals

Social networking techniques are also used to support relatives and family carers in communicating and exchanging information with relevant others in the same situation. Such techniques are further applied to facilitate cooperative work between family carers and care

professionals. To support the care of older persons suffering from multiple chronic conditions, enhanced ICT infrastructures with improved support for coordination of work and cooperation are needed to ensure close interaction between the individual's personal environment and different health and social care providers' environments. To support daily cooperation and awareness of work processes and care interventions within trans-institutional home care teams, older patients and their next-of-kin, information integration architectures with ubiquitous information access and documentation possibilities have been designed [73].

6. Current trends, challenges and knowledge gaps

Future use of technology and informatics in ambient intelligent environments (AmIE) is often described in form of scenarios (for example [74,75]), and a number of projects are currently ongoing to get closer to the AmIE vision. Most of the scenarios were developed by AmIE enthusiasts, leveraging promising descriptions on how new technologies promise to make our lives more efficient, enjoyable, productive and enriching. Futurists like Bushko [76], for example, envision the future in form of 'Healthons', small distributed affective intelligent caring creatures, that are implanted in our bodies or embedded everywhere, able to communicate to each other, and able to explain what is happening with our health at any moment. Others provide more critical and realistic scenarios [77,78]. Also, the European project 'Safeguards in a World of Ambient Intelligence (SWAMI)' [79] develops 'dark scenarios' are developed to highlight the threats to privacy, identity, trust, security and inclusiveness posed by the new technologies.

Reviewing the current state of the literature and ongoing projects, the following knowledge gaps can be identified. From a technical point of view, standardisation of sensor-based home and body area networks as well as standardisation for information integration is still crucial. This also includes methods for data fusion, context awareness and usability, safety and security issues. From a clinical point of view, impact on quality of life, quality of care and the medical impact of measurable parameters need to be evaluated. From the point of view of social sciences, legal, ethical, policy and gender aspects need to be studied further as well as new business models.

7. Conclusion

Technology and aging as an area of research has expanded during the last decade, engaging researchers from different scientific fields that can only be adequately tackled by a cross-disciplinary research approach. The biggest challenge in this regard is to accommodate the need for a holistic integrated service which means to provide personalised services and adapt technology and content to individual needs of different stakeholders. Here, the social dimension needs to be fully understood, clinical pre-requisites have to be considered and appropriate and usable technological solutions must be developed under close surveillance of a legal and ethical regulatory framework.

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