Health-Enabling and Ambient Assistive Technologies: Past, Present, Future

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Summary

Background: During the last decades, health-enabling and ambient assistive technologies became of considerable relevance for new informatics-based forms of diagnosis, prevention, and therapy. **Objectives**: To describe the state of the art of health-enabling and ambient assistive technologies in 1992 and today, and its evolution over the last 25 years as well as to project where the field is expected to be in the next 25 years. In the context of this review, we define health-enabling and ambient assistive technologies as ambiently used sensor-based information and communication technologies, aiming at contributing to a person's health and health care as well as to her or his quality of life. **Methods**: Systematic review of all original articles with research focus in all volumes of the IMIA Yearbook of Medical Informatics. Surveying authors independently on key projects and visions as well as on their lessons learned in the context of health-enabling and ambient assistive technologies and summarizing their answers. Surveying authors independently on their expectations for the future and summarizing their answers. **Results**: IMIA Yearbook papers containing statements on health-enabling and ambient assistive technologies appear first in 2002. These papers form a minor part of published research articles in medical informatics. However, during recent years the number of articles published has increased significantly. Key projects were identified. There was a clear progress on the use of technologies. However proof of diagnostic relevance and therapeutic efficacy remains still limited. Reforming health care processes and focussing more on patient needs are required. **Conclusions**: Health-enabling and ambient assistive technologies remain an important field for future health care and for interdisciplinary research. More and more publications assume that a person's home and their interaction therein, are becoming important components in health care provision, assessment, and management.

Keywords

Medical informatics, biomedical engineering, health informatics, ambient assisted living, health-enabling technologies.

1 Background and Objectives

1.1 Background

During the last decades, health-enabling and ambient assistive technologies became of considerable relevance for new informatics-based forms of diagnosis, prevention, and therapy. In this context, the editors of the IMIA Yearbook of Medical Informatics assigned an exciting task to us. For its 25th volume we were asked to "describe the state of the art of health-enabling and ambient assistive technologies in 1992 and today, and its evolution over the last 25 years." The editors "would like to see a discussion where the expectations for the field were in 1992, if they were realized and what particular events occurred that disrupted, derailed, or accelerated the planned development (political, technical, societal, etc.). Another dimension to cover is a projection of where the field is expected to be in the next 25 years." [1].

1.2 Objectives

For accomplishing this task we tried to reflect on three *questions*:

[past]   How did research on health-enabling and ambient assistive technologies evolve during the last 25 years?
[present] Where are health-enabling and ambient assistive technologies today?
[future]   What can be expected in the near future and, maybe, in about 25 years?

As [past] we defined the time from 1992, the year, where the first volume of the IMIA Yearbook appeared, to 2011 (i.e. not only 1992), as [present] the time from 2012 to 2015 (i.e. not only 2015, the year where this manuscript was written). As [future] we considered the next 25 years, i.e. the time from 2016 to 2041.

The *approaches*, we selected, to receive answers to the questions for the [past] and the [present] were to report

[pub]   on selected publications,
[kpv]   on some key projects and visions, and
[lel]   on lessons learned

regarding health-enabling and ambient assistive technologies. As suggested by the Yearbook editors, for [lel] we tried to consider aspects of information processing methodology and information and communication technology as well as political and societal aspects.

For the question on the [future], the approach, we selected, was to present our views

[next25y] on where the field is expected to be in the next 25 years and
[aspects] on which methodological and technological aspects as well as which political and societal aspects should be considered.

1.3 Limitations

Readers should be are aware that our answers to [past].[kpv], [past].[lel], [present].[kpv], [present].[lel], [future].[next25y] and [future].[aspects] are subjectively biased. Even for [past].[pub] and [present].[pub], by defining our search strategy, a certain degree of subjectiv-

ity cannot be avoided. Also, we will mainly focus on research in this field, and less so on practice and education.

1.4 Structure

Before presenting our answers to questions [past] in section 4 and [present] in section 5, with respective sections for [pub], [kpv] and [lel], and to [future] in section 6, with sections for [next25y] and [aspects], we had to define our understanding of the term health-enabling and ambient assistive technologies in section 2. The methods we chose, on how to obtain answers to the three questions with its respective approaches, are presented in section 3.

2 What are Health-Enabling and Ambient Assistive Technologies?

2.1 What they are

Health-enabling and ambient assistive technologies are, according to our understanding, ambiently used sensor-based information and communication technologies, aiming at contributing to a person's health and health care as well as to her or his quality of life.

2.2 Synonymous Terms

Synonymous or at least very close terms in this context are, in our opinion, the terms ambient assisted living for health care [2], ambient assistive technologies for health care [3], ambient intelligence for health care [4], health-enabling technologies [3], pervasive computing technologies for health care [5], pervasive health [6], pervasive health care [7], smart home technologies for health care [8], and ubiquitous health care (uHealth, [9]).

2.3 Objectives and Users

As mentioned in section 2.1, health-enabling and ambient assistive technologies intend to contribute to a person's health and health care as well as to her or his quality of life [10]. Often such persons do or may in the future suffer from functional impairments. These impairments can be related to advanced age [11].

Criteria for contributing to health care may be that these technologies contribute to make care affordable, efficient, and/or of high-quality. Quality of life often includes as a major aspect self-determined and self-sufficient (autonomous) life styles, while informational self-determination and data privacy are preserved. Further, these technologies help to enable social inclusion in spite of impairments as well as a life with dignity.

In supporting new ways of living and new ways of care (Figure 1, from [12], p. 86), health-enabling and ambient assistive technologies intend to support activities of health care and of preventive health [13]. Tools based on these technologies may be used by the respective person herself or himself, by health care professionals (nurses, physicians, ...), and/or by informal care givers (close persons, relatives, ...), who are taking care of this person.

2.4 Ambience, Sensors and Services

Ambiently, as mentioned in section 2.1, means that sensors are typically used either

- in persons' living environments such as homes (with room-based sensors, e.g. for motion analysis) or in other daily environments of persons like e.g. cars, workplaces, or shopping centers. Or they are used

- on a person's body (with body-based sensors, e.g. for acceleration measurement). Such body-based sensors can even be immersive or implanted (e.g. in pace makers or in knee prostheses).
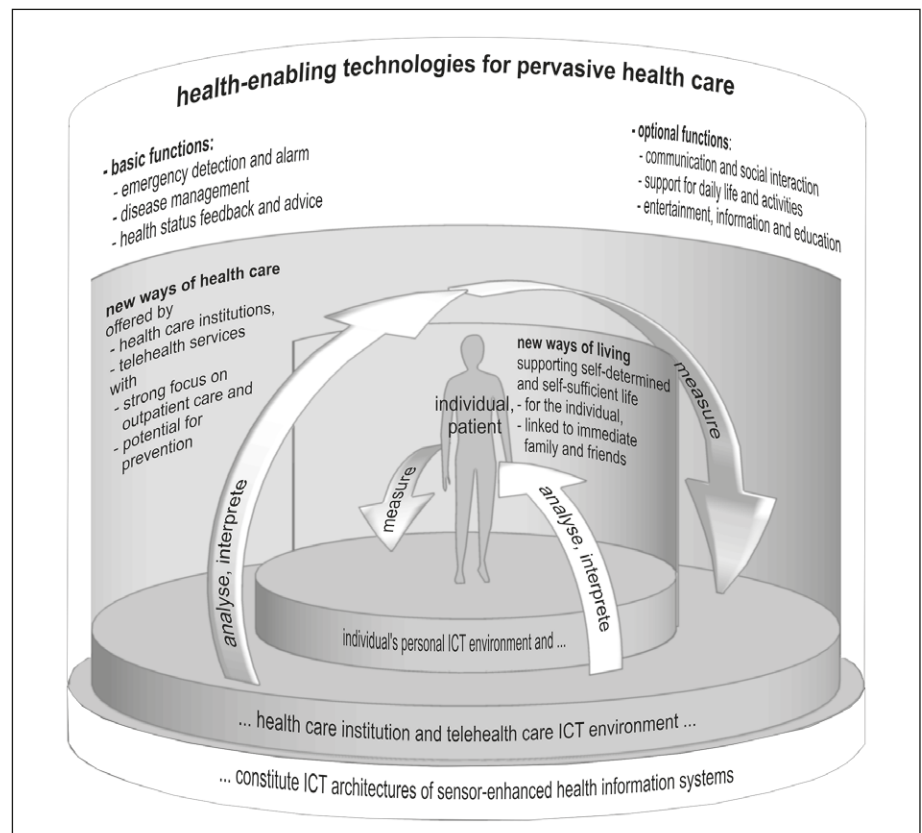

Fig. 1 The double circle: new ways of living and new ways of health care supported by health-enabling and ambient assistive technologies (from [12], p. 86).

By using sensors a variety of signals can be measured, e.g. acoustic, video, bioelectric (like cardiac signals), optical, pressure, and temperature signals like body temperature [14, 15]. Most activities of daily living can be recorded using for example door contact switches, motion sensors, power meters, and vibration sensors (e.g. in drawers). Last but not least wearable acceleration sensors and/or sensors for identifying a person's location (e.g. via GPS) are of importance in this context. Many of these sensors are inexpensive. Sometimes they are already available in existing tools like mobile phones.

Basic services being supported by health-enabling and ambient assistive technologies are

- emergency detection and notification (e.g. for fall detection, [16, 17]),
- disease management (usually for chronic diseases, e.g. coronary artery disease, and often based on measuring and analyzing activities of daily living) and
- health status feedback and advice (consultation [18]).

These services may be accompanied by supporting non-health related 'social' services like communication and social interaction tools (with peers, close persons, relatives, care givers, ...), and/or general services supporting daily life through education, entertainment, information, and wellness management ([12], pp. 82-83, [19]).

2.5 Health Information Systems and Electronic Health Records

Health-enabling and ambient assistive technologies should also be viewed as components of health information systems (HIS), which support health care processes ([20] chapter 4). In HIS terminology these tools are certain computer-based application systems, which are installed on physical subsystems like computer systems and support specific services (as mentioned in section 2.3). Such services are in the context of HIS usually called (enterprise) functions.

As such application systems on the physical layer include sensors, HIS using such tools are called sensor-enhanced HIS [21, 22]. As for the functions, listed in sec-

tion 2.3, usually more than one health care institution is involved and since a person's home is typically also included, such HIS are also denoted as transinstitutional HIS ([20] section 4.3, [22]).

Data from such health-enabling and ambient assistive technology tools and findings based on these data (which may be derived automatically, semi-automatically, or manually) may or perhaps should become part of a person's electronic health record [23]. The applications must be understood as informatics diagnostics and informatics therapeutics tools ([24], p. 606).

2.6 What They Are not

Health-enabling and ambient assistive technologies differ

- from ambient assisted living, ambient intelligent, pervasive, ubiquitous and/or smart home technologies (although having been mentioned in section 2.2), if no contribution to a person's health and health care or her or his quality of life is intended;
- from 'conventional' information and communication technologies as well as from technologies used in eHealth [25, 26, 27], mHealth [28], telemedicine/telehealth [29, 30], and/or telemonitoring [31, 32] where sensors are not used in an ambient way as described in section 2.4;
- from sensor-based tools for wellness management, if these tools are primarily used for lifestyle and sports and if they are not related to health care or to preventive health [28].

Certainly there are grey zones in differentiating health-enabling and ambient assistive technologies from some technologies mentioned above.

3 Methods

3.1 Overview

To receive answers to the questions stated we chose the *methods* presented in table 1. The report on selected publications (in sections 4.1 and 5.1) can be regarded as systematic review according to the PRISMA statement [33].

3.2 How Publications Were Selected
Articles Included

For `[pub]` all original research articles published in the IMIA Yearbook volumes 1 (in 1992) to 24 (in 2015) were included in our search. These papers had a clear focus on research and were

- either original articles written for a Yearbook volume (e.g. IMIA Yearbook reviews, surveys, but also keynotes, prefaces, working group contributions[1], as well as IMIA award articles)
- or original articles having been published first elsewhere and having been selected as 'best papers' (and until 2005 also reprinted) in a Yearbook volume.

We excluded articles from our search, if they were assigned as comments, editorials, introductions, obituaries, President's statements, reports about IMIA (and its members, working groups, etc.), reports about Medinfo conferences, synopses, as well as articles in codes of ethics, education[2], history, in memoriam, and white paper sections.
A list of the included and excluded articles can be obtained upon request to the first author.

Articles Selected

From the included articles the authors (Table 1) independently selected those manuscripts, which covered health-enabling and ambient assistive technologies as defined in chapter 2.

To determine if a Yearbook article met the mentioned selection criterion, the content in the Yearbooks was used, which mostly (but not always) were the articles' full texts. IMIA Yearbooks are available in print for the years 1992 to 2013 and in electronic form since 2006[3].

For selected manuscripts each of the respective authors wrote a brief summary. In case that an article had been selected by

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[1] if they were published as original articles, i.e. since IMIA Yearbook 2011

[2] usually two sections per Yearbook, with varying names such as education, computer-supported education, education and consumer (health) informatics, education and training, and research and education

[3] at http://www.schattauer.de/en/magazine/subject-areas/journals-a-z/imia-yearbook, last access: November 28, 2015

Table 1 *Methods* chosen (with time frames and responsible authors) to answer the three *questions* raised and presented with their respective *approaches* and references to the sections, where results are presented. Abbreviations were introduced in section 1.

question	approach	abbr. (sect.)	Method	time	auth.
How did research on health-enabling and ambient assistive technologies evolve during the last 25 years?	To report on selected publications.	`[past].[pub]` (4.1)	Summarizing selected IMIA Yearbook articles.	1992 - 2011	M.M. R.H.
	To report on some key projects and visions.	`[past].[kpv]` (4.2)	Authors select up to three key projects or visions.		all
	To report on lessons learned.	`[past].[lel]` (4.3)	Authors provide up to three major lessons learned.		all
Where are health-enabling and ambient assistive technologies today?	To report on selected publications.	`[present].[pub]` (5.1)	Summarizing selected IMIA Yearbook articles.	2012 - 2015	K.-H.W. R.H.
	To report on some key projects and visions.	`[present].[kpv]` (5.2)	Authors select up to three key projects or visions.		all
	To report on lessons learned.	`[present].[lel]` (5.3)	Authors provide up to three major lessons learned.		all
What can be expected in the near future and perhaps in about 25 years?	To present views on where the field is expected to be in the next 25 years.	`[future].[next25y]` (6.1)	Authors describe their views.	2016 - 2041	all
	To present views on which methodological and technological aspects as well as which political and societal aspects should be considered.	`[future].[aspects]` (6.1)	Authors describe their views.		all

both authors, it was included in the set of selected articles, and the two summaries were merged and edited.

In case that only one author selected an article, the authors reached consensus on whether the article should be selected or not. If yes, the available summary was either used as written or edited.

3.3 How Key Projects, Visions, Lessons Learned, and Expectations on Future Aspects Were Compiled

For `[kpv]` all authors were independently asked:

"Please select up to three key projects and/or visions (with references) regarding health-enabling and ambient assistive technologies
[past]   in the time from 1992 to 2011 and
[present] in the time from 2012 to 2015

and please report briefly why these projects or visions had been of importance. Key projects and visions can be by other persons (research groups, ...) or by you (e.g. on projects where you were/are part of the respective research group)."

For `[lel]` all authors were independently asked:

"Please list up to three lessons you learned regarding health-enabling and ambient assistive technologies
[past]   in the time from 1992 to 2011 and
[present] in the time from 2012 to 2015.
Please consider aspects of information processing methodology and information and communication technology as well as political and societal aspects."

For `[next25y]` all authors were independently asked:

"Please describe briefly the anticipated changes to the field of health-enabling and ambient assistive technologies in the next 25 years, i.e. in the time from 2016 to 2041."

For `[aspects]` all authors were independently asked:

"Please describe briefly which methodological and technological aspects as well as which political and societal aspects should be considered in the next 25 years, i.e. in the time from 2016 to 2041."

After receiving the answers, the first author combined all results and edited them. As the answers varied in length, most were too long to be presented in detail and were shortened. Frequently, a presented topic was mentioned by more than one of the authors. Also, closely related topics were combined. For all texts presented here, approval was given by all authors.

4 Health-Enabling and Ambient Assistive Technologies: The Past

4.1 Selected Publications

Table 2 contains the selected articles on health-enabling and ambient assistive technologies. Please note that the term review in table 2 has been used in a very broad sense. Originally, we wanted to select only papers, whose *major content* was health-enabling and ambient assistive technologies. We discovered, however, that while many papers clearly touched this field, the field was not the *major* content. We finally decided to include only papers with *major content* in health-enabling and ambient assistive technologies.

Papers containing statements on health-enabling and ambient assistive technologies are published rather late with the first year being 2002, in the Yearbook's 10th volume. From 2005 onwards, in nearly each Yearbook volume, papers with this content could be found. These papers however form a minor part of published research articles in medical informatics (20 out of 320 articles between 2005 and 2011, i.e. about 6%).

Before 2002, there were several Yearbook publications on telemedicine which we did not to include according to our definitions. Perspective papers on visions using these technologies form a considerable part of the selected publications (5 articles of 20). Included papers were spread over various sections of the IMIA Yearbooks.

4.2 Some Key Projects and Visions

The authors were significantly influenced by research groups led by (in alphabetic order) George Demiris (USA), Paul Lukowicz (Germany), Dimitar Stefanov (Bulgaria), and Gerhard Tröster (Switzerland). Some of their papers were already mentioned in section 4.1. Other methodical papers and project reports which authors identified as seminal to their own research were [66, 67, 68, 69, 70, 71, 72, 73, 74].

One of the first demonstrations of health-enabling and ambient assistive technologies was reported in [75]. A multidisciplinary research project with associated field trials in New South Wales, Australia used ambient sensing technologies configured to record occupancy and utilization of resources of older persons living at home alone. It was a decade before wireless technology was routinely being used for similar measurements.

Other key projects identified by the authors included PlaceLab (MIT, [76, 77]), INCA (EU, [78]), the Veterans Health Administration US home telehealth program [79], HealthDesign (a US national program, [80]), and GAL (Lower Saxony, Germany [81]), FitForAge (Bavaria, Germany [82]), and OASIS (EU, [83]).

PlaceLab was an apartment that was equipped with a wide range of sensors. It was one of the first installations to observe people living under realistic conditions in an environment totally controlled and observed by researchers. The INCA project aimed at improving diabetes therapy by creating a personal closed-loop system interacting with a telemedical remote control. It was among the first projects including two loops, one direct patient to patient loop and one with the medical professional in the extended telemedical loop. Between 2003 and 2007, the Veterans Health Administration's 'Care Coordination/Home Telehealth' program intended to coordinate the care of veteran patients with chronic conditions and to avoid their unnecessary admission to long-term institutional care. The GAL network researched from 2008 on the topic of design of environments for aging from a variety of perspectives. Researchers from many different disciplines shared their visions, concerns, and perspectives, and applied the theoretical results by developing use cases that they implemented and tested in real life. FitForAge concentrated on supporting mobility and life at home and in work environments as application scenarios, with cross-sectional topics on systems development and products and services. OASIS focused on developing ICT architectures for products and services in ageing societies.

4.3 Lessons Learned?

We concluded that testing and understanding technology was a major issue during this phase. In the beginning health-enabling and ambient assistive technologies were expensive and with limited performance and stability. Much of the development was technologically driven. So developments were often not based on clinical needs or the needs of patients. Measuring activities and vital signs with body-based or room-based sensors and understanding the meaning of the data measured in the context of diagnosis, therapy, prevention, and safe living were of importance.

There was also a gap between the visions presented and the reality of using such technologies. Fall detection and fall prevention was a priority area of research. New disease management opportunities became available through this technology as individuals worked with their health care providers to learn to manage their own diseases. However, studying disease or falls in the frail elderly was hugely expensive because of the complex co-morbidities (and thus heterogeneous patient cohorts) and the fact that disease progression can often be slow. Thus randomized clinical trials aiming to demonstrate improved patient health outcomes must be conducted for many years leading to many reports in the literature of pilot studies that frequently did not reach statistical significance.

In addition to being able to use and control these new and promising technologies, it became clear that care process change had to be considered, e.g., by adapting standards (e.g. communication standards) and even laws. For communication standards, the eHealth resolution of the World Health Assembly was important ([84], see also [85]), however progress was slow. Progress in adapting laws was even more disappointing. Introducing reimbursement for these new care processes was very limited and became another factor slowing progress.

Unfortunately, educational programs in biomedical and health informatics seldom considered these technologies in their programs. This prevented progress in improvement of health care processes and of our understanding how data from such technologies should be analyzed and become part of a person's health record.

Table 2 IMIA Yearbook articles in volumes / *years* 1992 to 2011 with a major content on health-enabling and ambient assistive technologies. *Articles* are *referenced, briefly described* and characterized by article *type* - articles containing primarily specific research (*sres*, e.g. presenting a study and/or methodology / technology), a review (*rev*), or perspectives (*psp*). We also included the *yearbook section name, n(i)*: number of articles included, and *n(s)* number of articles selected per year.

			article			
year	n(i)	n(s)	reference	description	type	Yearbook section
1992	55	0				
1993	50	0				
1994	41	0				
1995	49	0				
1996	41	0				
1997	48	0				
1998	38	0				
1999	44	0				
2000	38	0				
2001	40	0				
2002	44	1	Haux R et al. Information processing in healthcare at the start of the third Millennium: potential and limitations. Yearb Med Inform 2002 [34] and Methods Inf Med 2001[35].	Includes visions of seamless patient monitoring and consulting as well as home treatment. „With low-cost high quality technology it will become possible to constantly monitor patients anytime and anywhere." „The seamless integration of multiple communication modes will lead to high-bandwidth telemedicine."	psp	challenges in medical informatics
2003	47	0				
2004	38	0				
2005	50	4	Lukowicz P et al. Wearable systems for health care applications. Yearb Med Inform 2005 [36] and Methods Inf Med 2004 [37].	Providing an overview of wearable technologies for health applications.	rev	ubiquitous health care systems
			Maiolo C et al. Home telemonitoring for patients with severe respiratory illness: the Italian experience. Yearb Med Inform 2005 [38] and J Telemed Telecare 2003 [39].	Intervention study on home monitoring of arterial oxygen saturation and heart rate for patients with severe respiratory illness, reporting on lower hospitalization costs after intervention.	srs	ubiquitous health care systems
			Schek H-J. Ubiquitous computing and pervasive health care. Yearb Med Inform 2005 [40].	Important „applications of ubiquitous computing" are „e-health and e-inclusion, i.e. modern IT for health care, disease management, and support for independent living of the ageing society."	psp	preface
			Tröster G. The agenda of wearable healthcare. Yearb Med Inform 2005 [41].	Presenting the vision of a wearable personal health assistant for disease management, rehabilitation, and prevention.	rev	review section
2006	36	4	Anliker U et al. AMON: a wearable multiparameter medical monitoring and alert system. Yearb Med Inform 2006 [42] and IEEE Trans Inf Technol Biomed 2004 [43].	Describing AMON, a „wearable medical monitoring and alert system", with AMON being evaluated in a study with volunteers.	srs	health information systems
			Cappuccio FP et al. Blood pressure control by home monitoring: meta-analysis of randomised trials. Yearb Med Inform 2006 [44] and BMJ 2004 [45].	Determining effects of home blood pressure monitoring in the context of essential hypertension in a meta-analysis of randomized trials. Report about positive effects of home blood pressure monitoring.	rev	assessing information technologies for health
			Kuhn KA at al. Expanding the scope of health information systems. Challenges and developments. Yearb Med Inform 2006 [46].	Addressing mobile systems and ubiquitous computing in the context of sensor-enhanced health information systems highlighting perspectives for home monitoring.	psp	health information systems
			Stefanov DH et al. The smart house for older persons and persons with physical disabilities: structure, technology arrangements, and perspectives. Yearb Med Inform 2006 [47] (summary) and IEEE Trans Neural Syst Rehabil Eng 2004 [48].	Analyzing the building blocks of smart houses with particular attention paid to health monitoring.	rev	health information systems

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Table 2 (continued)   IMIA Yearbook articles in volumes / *years* 1992 to 2011 with a major content on health-enabling and ambient assistive technologies. *Articles* are *referenced, briefly described* and characterized by article *type* - articles containing primarily specific research (*sres*, e.g. presenting a study and/or methodology / technology), a review (*rev*), or perspectives (*psp*). We also included the *yearbook section name*, *n(i)*: number of articles included, and *n(s)* number of articles selected per year.

year	n(i)	n(s)	article		type	Yearbook section
			reference	description		
2007	43	4	Istrate D et al. Information extraction from sound for medical telemonitoring. Yearb Med Inform 2007 [49] and IEEE Trans Inf Technol Biomed 2006 [50].	Sound surveillance system in the context of home care. „The originality of this research is to use sound as an informative source simultaneously with other sensors."	srs	sensor, signal and imaging informatics
			Konstantas D. An overview of wearable and implantable medical sensors. Yearb Med Inform 2007 [51].	Overview on wearable and implantable sensors and actuators for health care including home care.	rev	sensor, signal and imaging informatics
			Pärkkä J et al. Activity classification using realistic data from wearable sensors. Yearb Med Inform 2007 [52] and IEEE Trans Inf Technol Biomed 2006 [53].	Use of wearable sensors for improving awareness of daily activities in the context of healthy lifestyles.	srs	sensor, signal and imaging informatics
			Shea S et al. A randomized trial comparing telemedicine case management with usual care in older, ethnically diverse, medically underserved patients with diabetes mellitus. Yearb Med Inform 2007 [54] and J Am Med Inform Assoc 2006 [55].	Randomized trial on patients with diabetes mellitus. Intervention group with remote monitoring of glucose and blood pressure with electronic upload to electronic patient records resulting in improved case management.	srs	health and clinical management
2008	40	3	Demiris G et al. Technologies for an aging society: a systematic review of „smart home" applications. Yearb Med Inform 2008 [56].	Review of smart home technology projects and their functionalities. Authors comment that evidence for the impact on clinical outcomes is lacking.	rev	human factors
			Logan AG et al. Mobile phone-based remote patient monitoring system for management of hypertension in diabetic patients. Yearb Med Inform 2008 [57] and Am J Hypertens 2007 [58].	Blood-pressure monitoring system for remote hypertension monitoring of diabetic patients.	srs	health and clinical management
			Zheng JW et al. A wearable mobihealth care system supporting real-time diagnosis and alarm. Yearb Med Inform 2008 [59] and Med Biol Eng Comput 2007 [60].	Long-term monitoring of vital signs for high-risk cardiovascular patients through wearable shirts, ECG, respiration, and activity measurement.	srs	sensor, signal and imaging informatics
2009	54	1	O'Shea SI et al. Direct-to-patient expert system and home INR monitoring improves control of oral anticoagulation. Yearb Med Inform 2010 [61] and J Thromb Thrombolysis 2008 [62].	Intervention study on Internet-supervised patient self-management of oral anticoagulant therapy through prothrombin time monitoring at home. Positive outcomes for internet-supervised patient self-management.	srs	health and clinical management
2010	42	-				
2011	55	3	Demiris G et al. Smart homes and ambient assisted living applications: from data to knowledge-empowering or overwhelming older adults? Yearb Med Inform 2011 [63].	Highlighting how smart home and ambient assisted living systems utilize ubiquitous technologies including sensors.	psp	human factors and organizational issues
			Maeder AJ et al. Next generation telehealth. Yearb Med Inform 2011 [64].	Includes visions of ubiquitous connectivity and of self-care tools for „stimulating individuals to adopt and maintain a healthy ... lifestyle, enhanced by health sensor monitoring, interpretation of sensor data, visualization of health-related data, and providing individual custom health care guidance."	psp	towards health informatics 3.0
			Stroetmann V et al. Understanding the role of device level interoperability in promoting health - lessons learned from the SmartPersonalHealth Project. Yearb Med Inform 2011 [65]	Report on lessons learned from the ,SmartPersonalHome' project, highlighting the necessity of interoperability.	srs	sensor, signal and imaging informatics

5 Health-Enabling and Ambient Assistive Technologies: The Present

5.1 Selected Publications

Table 3 contains the selected articles with major content on health-enabling and ambient assistive technologies. The comments of section 4.1's first paragraph apply also for this section.

Health-enabling and ambient assistive technologies are still not in the center of medical informatics research, although papers with major content could be found rather continuously (in 3 of the 4 issues). 18 out of 231 articles (about 8% of the Yearbooks papers) addressed health-enabling and ambient assistive technologies as major content.

More and more publications assumed that a person's home is an important component in health care. There seems to be a trend that the home, with sensor systems specifically (and maybe temporarily) being used for health care, is becoming a new important area or space for diagnosis and therapy. As such the home would complement specialized health care 'areas' for inpatient and outpatient care such as hospitals, clinics, and general practices.

5.2 Some Key Projects and Visions

In the present, authors observed a shift to self-tracking of persons in the context of prevention and health care (but not exclusively). Studies about self-tracking behavior of patients with chronic diseases can be found in [108] and from quantified self-movement in [109] (see also the respective papers in 5.1). Technology is now much easier to use. The significant use of social media, smart phones, and accessories such as fitness trackers, smart watches, and digital appliances in the home environment paves the way for its exploitation in health care.

It is now possible to monitor aging patients, who live alone, around the clock using such technologies. In the context of new ways for health care, the Whole System Demonstrator project was discussed as a key project of significant importance to

the authors (WSD, e.g. [110]) as well as the GAL-NATARS study ([111], see also [112]).

The WSD project reported that for recruited patients with diabetes, chronic obstructive pulmonary disease, or heart failure the 12 month mortality rate was lower for intervention patients receiving telehealth services including health-enabling technologies than for patients in the control group (4.6% versus 8.3%). The GAL-NATARS study showed that health-enabling and ambient assistive technologies can become an important future component for home rehabilitation of geriatric fracture patients.

Other key projects discussed were cohort studies like the German National Cohort [113] and the UK Biobank Cohort [114], both with considerable amount of measured sensor data of persons included as well as the BASIS (Building Automation by a Scalable & Intelligent System) project which is exploring new ways of energy efficiency and safety for systems based on health-enabling and ambient assistive technologies [115]. The last aspect will be of growing relevance as such systems may have to be regarded as medical devices.

Further, authors commented on the global relevance of health-enabling and ambient assistive technologies, i.e. not only for developed but also for developing countries and mentioned the 'Portable Health Clinic' project for unreached people in Bangladesh [116, 117, 118]). There, a check-up health service has been provided by a sensor package combined with telemedicine for at-risk groups in villages and factories (total 16,741 subjects) in Bangladesh from 2012 on. The study suggests that this may be a cost-effective health check-up service based on their data mining analyses.

5.3 Lessons Learned?

We discuss in the section the lessons learned in regards to orientation in research and practice, methodology, technology, health care process integration, and ethics.

Today patients are becoming the main drivers in the collection of sensor data (quantified self-movement). Health-enabling and ambient assistive technologies are still mainly considered to support

health care processes rather being recognized for the impact they have on self-care processes as well. There is demand from the health care side, especially from clinical research, to collect patient data, but feedback mechanisms are often lacking. In addition to persons/patients and health care institutions/health care professionals, this technology creates a need to collaborate with other institutions, who are supporting the daily life of persons, e.g. with housing companies. Finally, further impact studies for diagnostic relevance and therapeutic efficacy are still missing, although today's technology seems to be now mature enough to conduct such studies. The need for large sample sizes has already been discussed in section 4.3. Exploring relevance and efficacy will, however, be crucial for progress in understanding and applying health-enabling and ambient assistive technologies.

It is now possible to monitor aging patients, who live alone, around the clock by sensor networks. However, raw sensor data without any processing would exhaust physicians or medical staff. The lack of real world data to serve as examples is hindering the development of new methods to integrate data. Analysis techniques are still in their infancy. In the analysis of sensor data for ambulation and falls we learnt that many research groups worldwide fell into analysis and methodological traps that limit the generalizability and usefulness of some of the analyses and models reported in the literature. Some of the associated issues and lessons learnt are summarized in [119] and include overly-optimistic results in light of small sample sizes, questionable modelling decisions, and problematic validation methodologies. With the enormous increase in availability of rich sensor data and many possible analytical approaches, researchers are provided with the intellectual and creative freedom to explore datasets without constraints. However this new freedom must be treated with caution if we desire to create generalizable prognostic tools of any clinical value. Finally, research in more traditional fields like biosignal analysis and interpretation is now also including research on health-enabling and ambient assistive technologies, e.g.

Table 3 IMIA Yearbook articles in volumes / *years* 2011 to 2015 with major content on health-enabling and ambient assistive technologies. *Articles* are *referenced, briefly described* and characterized by article *type* - articles containing primarily specific research (*sres*, e.g. presenting a study and/or methodology / technology), a review (*rev*), or perspectives (*psp*). We also included the *yearbook section name*, *n(i)* : number of articles included, and *n(s)* number of articles selected per year.

			article			
year	n(i)	n(s)	reference	description	type	Yearbook section
2012	54	7	Demiris G et al. Mobilizing Older Adults: Harnessing the Potential of Smart Home Technologies. Contribution of the IMIA Working Group on Smart Homes and Ambient Assisted Living. Yearb Med Inform 2012 [86].	Highlighting "the potential of smart home applications to for older adults", with an emphasis on also providing opportunities for tailored interventions. A "theoretical framework for assessing mobility parameters and utilizing this information to enable behavior change" is presented and discussed.	psp	sensor, signal and imaging informatics
			Gogia SB et al. Using Personal Handheld Computing Devices for Personalizing Healthcare. Yearb Med Inform 2012 [87].	Exploring "the current status of personal handheld computing devices for personalizing healthcare", discussing that such "devices can be used to collect measurements and observations (e.g. motion, vital signs)".	rev	health information systems
			Khushaba RN et al. Driver drowsiness classification using fuzzy wavelet-packet-based feature-extraction algorithm. Yearb Med Inform 2012 [88] and IEEE Trans Biomed Eng 2011 [89].	Extracting and classifying driver drowsiness-related information from EEG, electrooculogram (EOG), and ECG signals.	srs	sensor, signal and imaging informatics
			Koch S et al. Critical advances in bridging personal health informatics and clinical informatics. Yearb Med Inform 2012 [90].	Investigating publications on the intersection of personal health and clinical informatics, discussing "sensor-based health-enabling technologies" and personal health systems and services "relying on the adoption of medical sensors".	rev	human factors and organizational issues
			Leong TY. Toward patient-centered, personalized and personal decision support and knowledge management: a survey. Yearb Med Inform 2012 [91].	Highlighting "the challenges and opportunities in decision support and knowledge management for patient-centered, personalized, and personal health care" including monitoring devices at home.	rev	decision support
			Paton C et al. Self-Tracking, Social Media and Personal Health Records for Patient Empowered Self-Care. Yearb Med Inform 2012 [92].	Investigating the use of "self-tracking technologies in the health sector". The use of "self-tracking tools, particularly in the health and fitness sector, but also used in the management of chronic diseases" appears to increase. However, evidence "of efficacy and effectiveness is limited to date".	rev	personal health and consumer informatics
			Wac K. Smartphone as a personal, pervasive health informatics services platform: literature review. Yearb Med Inform 2012 [93].	Exploring "current trends of mobile computing and communications technologies enclosed in a smartphone" enabling "the provision of personal, pervasive health informatics services".	rev	sensor, signal and imaging informatics
2013	61	4	Abbott PA et al. A scoping review of telehealth. Yearb Med Inform 2013 [94].	Reviewing telehealth literature for providing "a snapshot of some of the current developments in the field", referring to the "impact of data originating from ... sensing technology".	rev	health and clinical management
			Jeong S et al. An integrated healthcare system for personalized chronic disease care in home-hospital environments. Yearb Med Inform 2013 [95] and IEEE Trans Inf Technol Biomed 2012 [96].	Proposing a "patient status classification method for effectively identifying and classifying chronic diseases" in the context of joint "at-hospital and at-home" health care processes including the use of sensors.	srs	health and clinical management
			Klasnja P et al. Healthcare in the pocket: mapping the space of mobile-phone health interventions. Yearb Med Inform 2013 [97] and J Biomed Inform 2012 [98].	Identifying strategies "that have been used in mobile-phone health interventions" in health care processes.	srs	health and clinical management
			McCoy AB et al. State of the art in clinical informatics: evidence and examples. Yearb Med Inform 2013 [99].	Presenting recent evidence on clinical informatics in the US, also addressing, among others, mobile phones, which "can be used as sensory tools".	rev	evidence-based health informatics
2014	56	7	Capozzi D et al. A generic telemedicine infrastructure for monitoring an artificial pancreas trial. Yearb Med Inform 2014 [100] and Comput Methods Programs Biomed 2013 [101].	Example for homes, becoming a place for health care, which has formerly taken place in hospitals. "Combining ... wireless scales and blood pressure monitors with a mobile phone we were able to implement a home care platform providing automatic data acquisition for monitoring patients undergoing peritoneal dialysis".	srs	health and clinical management
			Carrault G et al. Are electronic cardiac devices still evolving? Yearb Med Inform 2014 [102].	Reviewing "some important issues occurring during the past year in implantable devices" including new opportunities for home monitoring.	rev	health information systems
			Hansen MM et al. Big Data in Science and Healthcare: A Review of Recent Literature and Perspectives. Yearb Med Inform 2014 [103].	Addressing the use of sensors in personal environments in the context of quantified-self activities.	rev	big data - smart health strategies

Table 3 (continued) IMIA Yearbook articles in volumes / *years* 2011 to 2015 with major content on health-enabling and ambient assistive technologies. *Articles* are *referenced, briefly described* and characterized by article *type* - articles containing primarily specific research (*sres*, e.g. presenting a study and/or methodology / technology), a review (*rev*), or perspectives (*psp*). We also included the *yearbook section name*, *n(i)* : number of articles included, and *n(s)* number of articles selected per year.

year	n(i)	n(s)	reference	description	type	Yearbook section
(2014)			Luna D et al. Challenges and potential solutions for big data implementations in developing countries. Yearb Med Inform 2014 [104].	Describing "the challenges and possible solutions for developing countries when implementing Big Data projects", addressing sensors in personal environments and recommending to take "advantage of the high penetration rates of mobile phones to collect usage-associated data and sensor data".	psp	big data - smart health strategies
			Redmond SJ et al. What does big data mean for wearable sensor systems? Yearb Med Inform 2014 [105].	Discussing how "recent developments in the field of big data may potentially impact the future use of wearable sensor systems in healthcare."	psp	sensor, signal and imaging informatics
			Safran C. Reuse of clinical data. Yearb Med Inform 2014 [106].	Discussing that sensors "in the home and on a person can already generate vast quantities of clinical data". "Non-traditional sources of health data that are patient-sources will pose new data science challenges."	psp	health and clinical management
			Vimarlund V et al. Big data, smart homes and ambient assisted living. Yearb Med Inform 2014 [107].	Discussing how "current research in the area of smart homes and ambient assisted living will be influenced by the use of big data".	psp	sensor, signal and imaging informatics
2015	60	-				

The table spans the top of the page with an "article" header over the reference, description, type, and Yearbook section columns.

[120] on assessing depressive states, [121] on detecting sleep apnea, and [122] on the use of bed sensors for heart rate monitoring in a recent focus theme of Methods of Information in Medicine.

Nowadays, the emergence of low-cost ubiquitous and energy-efficient wireless technologies [123] and accepted industry standards created wide appeal for wearable sensors to be used for monitoring human movement and for detecting and preventing falls (see [124] for a review). Similar technologies are also having a wide impact in the health informatics area in general (see [125] for a review). From an ambient assistive technology viewpoint, wireless technologies have been a significant enabler as they simplify installation and retrofitting of technologies into living spaces.

For health care process integration, technical means have to be developed to integrate data with classical health data in electronic health records to allow easy access and interpretation by health care professionals. Most of the information gathered resides in isolated silos. Integration of patient data from various sources (e.g. from hospitals and sensor data from a patient's home) into a coherent data repository is also a challenge to be solved (see e.g. [126, 127, 128, 129]). While silos in this context could be seen positively from a data security aspect, they often just hinder the use of the information for the benefit of its producer. Linked data between two or more sensor devices will probably create new useful information. For example, in Japan in the 1990's, diabetic patients could upload self-monitored blood sugar data via the Internet and browse data represented by graphs using the concept of 'information medicine'. However, this service was eliminated after several years because the additional value created by a single kind of data in graph form, may not be efficient enough to sustain the service. Finally, reimbursement for data analysis from health-enabling and ambient assistive technologies and liability issues for physicians treating patients based on such data are still not solved sufficiently.

A broad ethical discussion about who owns the data, who is allowed to process it under which constraints, and what should be done with the results is needed. The relevance of ethical, legal, and social implications (ELSI) of health-enabling and ambient assistive technologies is now recognized (e.g. [112]) and needs further attention.

6 Health-Enabling and Ambient Assistive Technologies: The Future

6.1 Where is the Field Expected to be in the Next 25 Years?

We highlighted different aspects of the future development of health-enabling and ambient assistive technologies. One author was already involved in predictions at the turn of the century [130] and re-examining these prognoses a few years ago [131, 132]. Based on these experiences we agreed that there are limitations to such prognoses and their constraints should be taken into consideration for the list of statements in this section. The following statements are somewhat unstructured, but we felt that this listing is probably the best way of presenting the statements.

In 25 years from now health-enabling and ambient assistive technologies will not even be recognized as such. They will be an integrated part of the health system. These technologies will only form parts of the 'big picture' and need to be integrated with other types of data or services such as a genetics-enhanced electronic health records and personals health records. There will be different scenarios of use:

- health-enabling and ambient assistive technologies will be used for population screening;
- patients with chronic diseases use them continuously to track their health or temporarily to achieve a specific aim, e.g. adjustment of medication;
- measurements from these technologies form part of the patient reported outcome measures (PROMs) and patient reported experience measures (PREMs).

Health-enabling and ambient assistive technologies will become more 'ambient' still and will be accepted for specific tasks such as chronic disease monitoring. Insurance companies will adopt this idea if sound studies show potential cost cuts.

Sensors will become capable of measuring medically relevant parameters unobtrusively and non-invasively (blood glucose for example).

Epidemiological studies will change because of new measurement methods of 'exposome' data through health-enabling and ambient assistive technologies (data from a person's environment, her/his activities especially in terms of 'behavior').

Potentially a countermovement of non-adopters of sensor technology could develop with individuals objecting to measuring every detail in life and raising awareness of unfavorable behavior ('prevention dilemma' and conscious disregard of the right thing to do).

Unobtrusive and wearable sensor data are of little value unless they can be interpreted and the potentially big data sets collected can be transformed into knowledge bases. Validated clinical decision support systems that may be used to infer changes in health status appropriate for ambient assisted living data will be developed.

Such developments should align with the progress in developing personalized models

of a patient's health – driven to a large extent by the progress in projects related to the virtual physiological human and the physiome, which allow the integration of complex computational models spanning many temporal spatial and temporal scales. Thus the link between genome, to proteome, to cell and organ specific in an individually customisable fashion will be achievable. Health-enabling and ambient assistive technologies will allow this personalized medicine to be measured, delivered, and managed at the point-of-care, potentially within the patient's home environment.

The wireless sensing technologies used for this management will likely diverge into two categories. The first will be pervasive and unobtrusive devices that monitor persons and their interaction with their environment with no direct connection to the individual, thus eliminating many issues relating to compliance in taking measurements or attaching and wearing sensors. One example of this technology approach includes contactless biomotion measurement using radiofrequency sensing to assess sleep-disordered breathing [133]. Other technologies using automated video recognition and terahertz imaging will extend the range of unobtrusive sensing. The second category of sensing will be embedded into implantable devices, which may be purpose-implanted for example to monitor physiological function or gait, or be integrated into an existing device to extend its functionality. One example is the inclusion of triaxial accelerometry devices into a number of regulatory approved medical devices such as spinal cord pain nerve stimulators and implantable heart pumps. Such sensors could easily be used for detecting falls in future generations of these technologies.

In place of hospitals, home care should be the main site of nursing care for elders and disease/health care management worldwide. To avoid a decrease in the quality of service, sensors devices are expected to monitor patients/elders around the clock, more effectively than the nursing staff at a hospital. The keywords are cheap, reliable, and user-friendly for these devices. Processing data from these devices and delivering feedback for the home care site will avoid sending of raw data without any direct processing to physicians/hospitals.

The main beneficiary of these advancements seems to be the wealthy population

in developed countries. However, we should in future focus health-enabling and ambient assistive technologies also on poorer populations, even in developing countries. Methodologies that can provide services by database service, as a disease/health care management to poor populations worldwide, should consider the overall cost-effectiveness.

Technology will become more mature. It will be possible to 'just use' off-the-shelf technology that is already used by people (future patients as well as health care professionals). This will allow for easier adoption of such new technologies.

In the future, more houses will be equipped with intelligent systems for lighting, heating, and security. In-house entertainment equipment (Surround sound, video, SmartTV) will be ubiquitous and integrated via networks. Wearable or mobile equipment will be common place as well. Utilizing those for the health benefit of the inhabitants is one aspect of the field.

We anticipate difficulties in integrating data for the health benefit of the users. There is a need for interoperability standards, which hopefully will emerge. Furthermore, a concept for the safe and secure handling of data is needed and must be developed. Otherwise, these data will become available to people, who will not act in the best interest of the person (e.g. shared on social media or distributed by similar means).

Like any new technology, health-enabling and ambient assistive technologies will see emergence and decline of particular formats and technologies until specific standards emerge (Similar to VHS and Betamax).

Finally, referring to an article on the past, present, and future of medical informatics [134] some of the aims mentioned there, relate to the question, where health-enabling and ambient assistive technologies will be in 25 years:

"Having in mind that today and in the near future (a) health has to be considered more and more as an integral and continuous part of life (not as health care within a limited time frame of a disease episode), [and] (b) medical informatics is addressing both, health professionals (plus their professional environment) *and* individuals/consumers (plus their social environment), ... future research fields ... might ... be ...

1 seamless interactivity with automated data capture and storage for patient care, and beyond (from perception to high-level semantic concepts, related to human-human, machine-machine, as well as human-machine interaction; 'beyond' in the meaning of not being restricted to certain disease episodes); ...

3 patient-centered data analysis and mining (with representations of patient data based on appropriate semantic concepts);

4 informatics diagnostics, where informatics tools (with corresponding methodology) form the major part of the diagnostic entity;

5 informatics therapeutics, where informatics tools (with corresponding methodology) form the major part of the therapeutic entity;

6 informatics capability-enhancing extensions, both mental and physical, to overcome (e.g. age-related) functional deficits (both external or internal to the human body, serving as implanted, immersive or external assistants, and providing a person with extended memories, senses, and connectivity); ...

9 identifying new disease patterns (e.g. using ubiquitously available patient information and medical/health knowledge, through, e.g., pervasively measured sensor data from individuals, and, e.g., by combining such data with molecular and clinical knowledge within social and living contexts); ...

11 elaborating concepts for appropriate health data bank architectures and for its organizations (allowing a range of local to global offerings for storing and maintaining personal health data);

12 elaborating concepts for patient-centered health information system architectures (within and in particular beyond health care institutions, allowing multiple usability of data) and its information management strategies (e.g. also considering data from ambient environments such as 'intelligent' buildings, and external, implanted or immersive body sensors);

with all these research fields being related to ... establishing and exploring the use of 'living labs'" ([134], p. 606-607).

6.2 Which Aspects Should be Considered?

On the question, which methodological and technological aspects as well as which political and societal aspects should be considered, authors again highlighted different aspects. As in section 6.1 the following statements are to some extent unstructured since we believed that this list is probably the best way of presenting the statements.

Health-enabling and ambient assistive technologies have, from a methodological viewpoint, the aim to improve health and health care, but we still have no evidence. Evaluation studies are needed [135]. These technologies need to be coupled to decision support. Methods to extract meaningful information to support decision making for different kinds of users are needed. From a technological viewpoint, we should consider a higher personalization of services, overcome issues of standardized data integration and interoperability (critical in regards to future decision support systems), as well as security and consent management.

Some of the most important aspects in the next 25 years will be ethical. Who owns the patient data? This is an old question in a new form. Already now patients request access to the data not only from their health records but also from implantable and wearable devices. But there is more. Who will own the value derived from this data? There is clearly a market for secondary use of patient data. More discussion on this topic can e.g. be found at [136].

The field of economics will contribute with theories and business models for two-or multi-sided markets.

In many respects the societal, political, and governance systems are major barriers to advances in this field. Even today there is a range of suitable assistive technologies that could be used extensively in patient management but are not because appropriate remuneration and health service delivery models need to be developed to accommodate the stakeholders involved in managing health through these new approaches. As newer sensing technologies become available and patients become more empowered by being able to monitor and manage their own health, the need for policy change will become even more apparent.

It can be expected that individual health, diseases, and medical costs during the course of a patient's life and lifespan will be predicted in much more detail unless there are limitations or regulations. The recent debate on the use of genomic information may also be of help to further discuss this context. Simultaneously, the threat of leaking private information has increased significantly. Not only the difficulty in obtaining health insurance, but the discrimination in marriage, employment, and career advancement could occur because of leaked data. We should develop methodologies for genome information storage, use, linking, and discarding the information.

With regard to societal aspects, it might be difficult to actually replace a physician, although we can easily imagine artificial intelligence systems' abilities to exceed a human physician's ability in the near future. We should consider societal aspects when, where, and how we can install such informatics systems into medical/health care services. Otherwise, it will be difficult to accept this advancement in medical/health care services, because clinicians do not want to be superseded in their position by artificial intelligence systems.

Technology that we describe as health-enabling technologies will merge in the everyday life of people. It will become natural for people to be observed by accompanying devices (nowadays smart phones, but that might be different in the future) and that these devices are embedded in a network of further devices owned by patients. Devices in this network will together be able to determine the status and trend of your health and wellbeing and persons will receive conscious and ambient advice on how to improve their health and wellness.

Patients should have full access to this information and should be able to share it with health care professionals. This either can be on demand, or pre-programmed in case of emergency.

The gathered information will be of great value for health care professionals. Like medical imaging or laboratory measurements today no serious health professional will ignore data gathered in a patient's everyday life. Likewise, the prescription of personalized drugs will be accompanied by the prescription of a

computer-program that will not only remind patients of administration, but also adapt the dosage depending on a patient's current needs. Besides pharmaceutical drugs, computer based treatment will have proven its efficacy and will be established in medical routine.

It will be of importance to close the loop between research in health-enabling and ambient assistive technologies and the practice of health care and safe living. The need for studies on diagnostic relevance and therapeutic efficacy has already been mentioned several times. This will be combined with a market for products and services for such technologies (see e.g. [137]). Appropriate methodology for analysing such health-related, heterogeneous, multimodal, and multilocal data must be further developed. Aspects like using the home as additional 'setting' for health care (in addition to inpatient and outpatient settings like hospitals, nursing homes, or clinics) has to be considered, combined with further discussions on ethical, legal, and social implications, energy efficiency, and security aspects in the context of medical devices. Laws need to be adapted. In addition to patients and their care givers and health care professionals, other groups of professionals in particular in the context of living (e.g. for housing, mobility and shopping services) need to be also involved.

7 Some Final Remarks

It was our attempt to describe the state of the art of health-enabling and ambient assistive technologies from 1992 to today and how it has evolved across the last 25 years, as requested by the editors of this Yearbook. As mentioned in section 1.3, there are various limitations. The search strategy could be modified and the primary focus on research might have been chosen differently. Our systematic review centered on publications of the IMIA Yearbooks. Other sources might have been considered. Finally, as mentioned, we can not completely avoid subjectivity in our replies to key projects and visions as well as to lessons learned.

Are there any conclusions to be drawn? Certainly, the authors are convinced that health-enabling and ambient assistive

technologies remain an important field for future health care and for (interdisciplinary) research in biomedicine and in the health sciences. And that a person's home is becoming an important additional 'institution' for health care.

Are there any recommendations and implications for future research? We tried to outline our views on this question in section 6. To put it in a nutshell: There was a clear progress on the use of technologies. However proof of diagnostic relevance and therapeutic efficacy is still needed.

The authors agree that there is still a long way to go and that it is a worthwhile and indeed necessary path to travel. We hope and look forward to reading a respective paper on the past, present, and future of health-enabling and ambient assistive technologies (independent of what they are called then, ...) in the 50th volume of the IMIA Yearbook.

Conflicts of Interest Statement
The authors do not see any conflicts of interest.

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