Chapter 1
From Computer Innovation to Human Integration: Current Trends and Challenges for Pervasive HealthTechnologies

Carsten Röcker, Martina Ziefle and Andreas Holzinger

1.1 Introduction

Identifying and understanding current trends and challenges for pervasive health technologies in the twenty-first century is a challenging endeavor [70, 108, 122]. It requires the careful consideration of two major trends and their interplay. A first line of research addresses emerging technological innovations over time. Technology itself has made substantial progress and has undergone a fundamental change over the last decades in both the medical sector as well as the field of information and communication technology, which brings a variety of new possibilities to provide and deliver medical services [56, 62, 83]. A second line of research addresses differences in the characteristics of target groups and user profiles [11, 109]. Today, users of medical technology show completely different requirements than earlier users of these technologies did. The diversity of users who come into contact with medical and/or information and communication technologies is constantly increasing [11, 69]. Hence, the adequate consideration of personal factors like gender or age as well as aspects of culture and ethnicity are key concepts for human-centered technology development [4, 31, 67].

At the same time, today's information and communication technologies touch a fragile cross-over point between surveillance and control on one side and support and personal benefit on the other [59, 77, 106]. Especially in the context of medical

C. Röcker (✉) · M. Ziefle
Human-Computer Interaction Center, RWTH Aachen University, Aachen, Germany
e-mail: roecker@comm.rwth-aachen.de

M. Ziefle
e-mail: ziefle@comm.rwth-aachen.de

A. Holzinger
Institute for Medical Informatics, Medical University Graz, Graz, Austria
e-mail: andreas.holzinger@medunigraz.at

A. Holzinger et al. (eds.), *Pervasive Health*, Human–Computer Interaction Series,
DOI: 10.1007/978-1-4471-6413-5_1,

technology, a sensible trade-off between benefits and empowerment of patients on the one hand and barriers and stigma on the other hand needs to be respected.

The potential of pervasive health technologies is connected to a multitude of possible benefits on different scales [83]. They reach from societal benefits on a macro level, in terms of meeting existing shortcomings with regard to the care of elderly and providing universal access to medical technology, up to individual benefits on a micro level, in terms of independent living. However, there are also serious concerns regarding the violation of personal boundaries and comfort zones as well as issues of data security and privacy [60, 85, 112, 119]. As current medical technology is increasingly entering private spheres and literally crosses personal borders in case of invasive technologies, questions of 'control,' 'intimacy,' 'trust,' 'risk,' and 'reliability' are critical aspects to address [5, 76]. Also, societal attitudes towards frail and old people as well as constructive handling of the ageism problem are serious issues which need to be considered [71, 73].

In addition to the negative and stigmatizing attitudes towards older persons in public perceptions of most societies [49, 120], older persons themselves regard a dependency on technology and the resulting perceived loss of autonomy and control as highly negative. This situation requires a profound change in the way the individual aspects are addressed and calls for more holistic concepts of balancing the various requirements that have to be met [52, 93]. Beyond the exclusive focus on the technological potential and feasibility of pervasive health services, the inclusion of human values, different usage contexts, and requirements of user diversity are key aspects for the successful development of pervasive health technologies [6, 121].

In the following, we first concentrate on the description of technical innovations and the way technology has changed over the years. In a second step, social and societal challenges are outlined. Bringing both lines together, the third part of this paper identifies future research challenges.

1.2 Technical Innovations

1.2.1 Intelligent Objects and Smart Environments

Over the past 50 years, we went through different phases of computing (see [94]). The years between 1960 and 1980 were characterized by mainframe computers that were primarily used by big companies, universities, and governmental organizations. With the emergences of smaller and more affordable computers in the 1980s, computing ushered into a new phase. Personal computers found their way into many offices and were used as general-purpose tools for a variety of office activities [79]. The third wave of computing started with the wide-spread availability of mobile devices and increased networking capabilities around the turn of the century. This so-called ubiquitous computing era enabled computing anytime and anywhere [80] (Fig. 1.1).

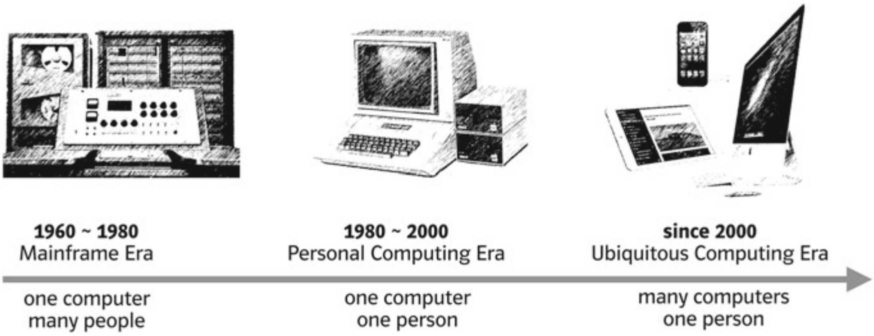

Fig. 1.1 Phases of Computing

During this time, we did not only see a tremendous increase in computing power, we also experienced a shift in the relationship between computers and users [81]. While early computing systems required an entire team of engineers and computer scientists to be operated and were jointly used by many people, this situation changed with the introduction of personal computing systems. This one-to-one relation between users and computers changed again with the emergence of mobile and embedded computers. Today, users interact with a multitude of computational devices throughout the day.

While this situation represents normality for many people, we are currently on our way towards a new era of intelligent, interconnected objects and smart environments in which more and more computers are embedded in our physical environment and unobtrusively support us in different areas of everyday life (see, for example, [35, 53, 84, 100]). In recent years, the term "Internet of Things" (IoT) is increasingly used to describe this vision. Especially in business literature, the original concept of ubiquitous or pervasive computing is often referred to as the Internet of Things. Projections about the growth of the IoT vary considerably. Estimates range from 15 billion [47] to 25 billion [29] interconnected devices in 2015, and from 50 billion [28, 29] to 100 billion [46] in 2020. Nevertheless, there is little doubt that a world of networked devices will be the next big step. Some authors even argue that the "IoT represents the future of computing and communication" ([34], p. 297).

1.2.2 Computing Moves to the Cloud

The Internet is often cited as one of the most influential developments of the last decades. Originally started as a project of the US defense department to enable the efficient usage of scarce computational resources in the late 1960s, the nature of the Internet changed significantly over the following decades [78]. While in the beginning access was restricted to a few research institutions, the wide-spread public usage of the Internet started in 1989 with the development of the World Wide Web (WWW), a global network of webpages. For the first time, the WWW enabled users to produce and consume content at the same time. However, its usage still required substantial computer knowledge. In 1993, this was fundamentally changed with the presentation of *Mosaic*, the first graphical web browser, which enabled easy access to web-based information. In the coming years, more and more companies and consumers discovered the Internet, which contributed to an immense increase in the number of users. While around 45 million people were using the Internet in 1997, the number of users increased to more than 1.8 billion in 2009. Today, over 2.7 billion people are using the Internet worldwide, and in the developed world even 78 % of the households are connected to the Internet [48].

The availability of broadband Internet lines and the introduction of flat-rate fees structures in the last decade contributed to a variety of new web-based services. Today, it is widely accepted that “cloud computing has emerged as a dominant paradigm” [46]. Cloud computing does not only allow distributed computing over a multitude of connected computational devices, it also enables nearly unrestricted access to information for end users. Many cloud services are provided on a pay-per-use basis or are free of charge, reducing the costs for users and thereby lowering the entry barrier. Cloud computing also enables device independence as most services can be accessed via web frontends which means that only a web browser is necessary that can either run on a personal computer, tablet PC or mobile phone. In addition, applications and personal data are usually stored on a third-party server in the Internet which enables a location-independent use of services. Cloud-based services denoted a substantial increase in the number of users over the last years which was fueled by a steep drop in the costs for broadband connections. Worldwide, prices for fixed broadband decreased by 82 % between 2008 and 2012 [48]. At the moment, an end of the cloud computing trend is not foreseeable. Instead, current estimates predict a further increase in cloud computing by 130 % within the next two years [95].

1.2.3 A World of Mobile Services

Besides cloud-based services, mobile computing is often regarded as the most important technological innovation of the last century [46]. With currently 6.8 billion active mobile phone contracts, the number of subscriptions comes close to the world population of 7.1 billion people [48]. In its 2013 report, the International Telecommunication Union ([48], p. 6) announced that “mobile-broadband subscriptions have climbed from 268 million in 2007 to 2.1 billion in 2013” which “reflects an average annual growth rate of 40 %, making mobile broadband the most dynamic ICT market.” And this trend is not restricted to mobile phones alone. Recent sales data show that mobile devices replace stationary computers in many areas. In the fourth quarter of 2012—and less than three years after their introduction—global shipment of tablets PC surpassed the shipment of desktop computers and notebooks or the first time [66]. With the widespread diffusion of mobile devices, it is highly likely that the usage of cloud services will further increase.

1.2.4 Collective Intelligence and User-Generated Content

The previous sections illustrated significant achievements in computer science which had a fundamental influence on our everyday life. However, not only technology was refined and advanced. The behavior of users and their attitude towards technology has undergone a significant process of change as well [123]. One of the most important changes of the last years is probably the increased willingness of users to generate web content. User-friendly webpages and new interaction concepts offer easy and intuitive ways of providing feedback and thereby contribute to a continuously increasing database. This independent collaboration in form of personal user feedback does not only increase the informational value of a specific webpage, it also contributes to the Internet as a whole: the more people contribute, the better the result. This effect is often referred to as collective or swarm intelligence. Group processes enable to accumulate knowledge in a way that goes far beyond what an individual would be able to achieve. A good example for such processes is open-source software. The collaboration of many independent programmers leads to sophisticated software, often on a par with commercial products. Open-source programs are written by dozens, sometimes even as many as thousands of individuals. None of these persons would have the ability to write the code on their own, neither from the technical programming skills required nor from the time that would be necessary to complete the code.

User-added value and collective intelligence are the founding principles of many Web 2.0 applications. This 'microwork' principle is the key to the success of most social media websites which would not be able to exist without the multitude of small contributions by a broad user base. Low technical entry barriers and high usability of most of today's websites are the basis for multi-party communication and the direct exchange of experiences and knowledge within communities.

1.2.5 Big Data and Knowledge Discovery

Biomedical sciences are becoming increasingly data intensive and require as well as advance new research strategies. Instead of following the classical research paradigm, i.e., to set the hypothesis first and then gain data from experiments designed to test this hypothesis, it is now the other way around. Consequently, data science is now established as the fourth paradigm in the investigation of nature [36], after theory, empiricism, and computation [14, 20]. Data science is the study of the generalizable extraction of knowledge from data [25]. The masses of unstructured information as well as dealing with large, complex, and often weakly structured data are often cited as mega challenges in biomedicine today [42]. The increasingly large amount of data requires new, efficient, and user-friendly solutions for handling biomedical data. With growing expectations of end-users, traditional approaches to data interpretation often cannot handle the demands. Consequently, new computational and user-centered approaches are vital for coping with this rising flood of data [42].

1.3 Societal Transformation Processes

In contrast to technical systems and devices of past centuries, technology usage is no longer restricted to single technical systems within the working context but increasingly enters all areas of daily life. In addition, more diverse user groups have access to these new technologies. Yet the development of technology still seems to be limited to the requirements and characteristics of young, technology literate males of the middle and upper class in Western societies [64, 89, 101, 116]. It is therefore highly imperative that the development of pervasive health technologies adequately addresses both the specificity and diversity of users. This is not only a matter of considering cognitive and sensory abilities and/or restrictions of target users, but also includes issues of technology acceptance and human values in the context of technology usage which are considerably affected by age and gender as well as culture and ethnicity. These three aspects will be briefly illustrated in the following sections.

1.3.1 Age, Technology Generation, and the Demographic Change

As a consequence to the demographic change [43], more and older adults are confronted with a broad range of technology that they have to understand and use in different situations of everyday life. Up to now, interfaces are often designed without considering the abilities and needs of this user group [64, 89, 116]. Another blind spot of today's system design is user differences in technology education and experience [114]. Although technologies are supposed to be accessible to everyone, a gap between computer literate and less computer experienced users (predominantly older users) emerges. In this context, it should be kept in mind that older users differ considerably with regard to their needs, abilities, and competencies [26, 69, 124]. This aggravates the situation especially for older adults, as the understanding of how technology works is mainly gained through upbringing and socio-cultural factors. Older adults were educated in times when technical devices were far less ubiquitous and complex [115]. In order to address elderly users as a growing consumer group, age-sensitive interface designs are needed [11].

1.3.2 The Impact of Gender

While there is a considerable number of studies addressing gender differences in the interaction with information and communication devices [105], comparably few studies addressed gender differences in the field of acceptance of medical technology [119]. However, especially gender seems to have specific importance for the acceptance of pervasive medical technologies. Research has shown that women report lower levels of computer-related self-efficacy and higher computer anxiety [1, 19, 32] as well as a lower perceived technical confidence when using technical devices [111]. As a consequence, more negative attitudes of women towards technology reduce the probability of active interaction and lead to a generally lower computer-expertise [88]. The lower technology aptitude and/or affection in general could also negatively bias the acceptance of medical technologies. In addition, there are gender-specific body-related attitudes that should be considered. Women have different standards of morality and ethics in comparison to males [58], especially in combination with expected physical harm [30, 55, 68]. This could also have an influence on women's evaluation of pervasive medical technologies and, in turn, modulate the acceptance attitudes. Furthermore, it was found that women have different health-related cognitions, connected to higher vulnerability perceptions towards feelings of physical threat [16, 90]. Additionally, the degree of risk-taking behaviors turned out to be gendered. Men have a higher risk threshold and take higher risks than women [104, 119]. Finally, the acceptance of invasive medical technology is of specific interest, given the gendered nature of the nursing profession which is associated with the traditional female role of caring for and nurturing others [113]. As women have a higher life expectancy, an increasing number of female seniors will be a major target group of pervasive health technology. Consequently, gender should be taken serious as a key factor of technology acceptance in the medical sector.

1.3.3 Ethnicity and Culture

A clear shortcoming of current research in the field of pervasive health is the discussion of interaction between technology, society, and culture. The claim for "universal access" and overcoming of the "digital divide" is related to political systems, socio-economic standards, and legal frameworks. Even today, there is a striking lack of knowledge of how society and culture affect technology acceptance and the underlying reasons for or against technology usage [98, 99]. Comparably few studies have been concerned with the investigation of technology acceptance across national boundaries [3, 10, 86, 96, 102]. It is highly probable that the knowledge about technology acceptance and its underlying framing conditions referring to highly developed western countries do not hold for other cultures and ethnical groups. Cultural beliefs, habits, and values form a cultural mental model [38] and impact the willingness to adopt and use medical pervasive technologies in different ways [23, 54, 61, 98].

Technology is never used in isolation but within a social and cultural context. Social taboos, legal and political constraints as well as ethical, social, and religious traditions and habits differ across cultures. These contextual factors influence how humans interact with technology [116] as well as how they evaluate the usefulness and the need of a technology [4, 21, 72, 82, 112].

Thus, users around the world do differ in perceptions, cognitions, and the individual styles of thinking, cultural assumptions, and values [45]. This especially applies to the developing world and countries with underdeveloped societal and economic standards. But it also applies to those countries that experienced a very fast technological change over the last years, strive for economic welfare, and that are keen on closing the technological gap to highly developed countries [8, 9]. Whether pervasive health technology is accepted in different cultures also depends largely on cultural mindsets of family care, as well as on cultural ageing concepts [109]. Last but not least, the openness to adopt pervasive technology also relies on societal frames and healthcare structures [21], which might imply a different form of social and societal responsibility of others. In addition, the cultural handling of illness and the acceptance of end of life decisions are highly culturally sensitive [15, 57, 91].

1.4 Resulting Research Challenges

The changes illustrated above lead to a variety of new research challenges of technical as well as non-technical nature. Some of the most important ones are addressed in the following sections.

One of the mayor technical research problems refers to the meaningful visualization of the vast amount of medical data that is collected and stored in pervasive health systems. In general, biomedical data models are characterized by significant complexity [2, 40]. This makes manual analysis by end users often impossible. At the same time, experts are able to solve complicated problems almost intuitively [74], often enabling medical doctors to make diagnoses with high precision without being able to describe the exact rules or processes used during their diagnosis, analysis, and problem solving [75]. Consequently, it is a grand challenge to work towards enabling effective human control over powerful machine intelligence by integrating machine learning methods and visual analytics, and thereby supporting human insight and decision making [39]. While *Human-Computer Interaction* (HCI) deals mainly with aspects of human perception, cognition, intelligence, sense-making, and most of all the interaction between human and machine, *Knowledge Discovery and Data Mining* (KDD) deals primarily with aspects of machine intelligence, in particular with the development of algorithms for automatic data mining. Both disciplines have large areas of unexplored and complementary subfields. Consequently, possible solutions to many current problems in data intensive systems may be found at the intersection of HCI and KDD. One very promising approach is to combine HCI and KDD in order to enhance human intelligence with computational intelligence [41] and enable end users to find and recognize previously unknown yet potentially useful and usable information.

Further technical challenges include solutions for unobtrusive and ethically acceptable patient monitoring [107], new forms of patient-centered interaction devices [63] as well as approaches for efficiently integrating such devices into a shared environment [103]. However, current research challenges are not restricted to the technical domain alone, but they also include more general questions and conceptual design decisions like viable solutions for integrating hospital and home care [33, 92], new concepts for independent rehabilitation [18] as well as ways of providing universal access to such solutions [17].

However, when addressing these challenges, it is important to also adapt the resulting systems and applications to the dynamically changing needs of a diverse and culturally biased user population. Against the background of user diversity, there are a number of reasons that the acceptance of medical technology distinctly differs from acceptance patterns of other technologies. First, medical devices are used for critical health conditions and essential usage, instead of only for communication and entertainment purposes as is the case for most modern information and communication technologies [12]. Second, beyond the importance of patient safety, medical technology refers to "taboo related" areas that are associated with disease and illness [65, 111, 119]. Third, medical technology touches serious personal and vital issues. As a consequence, medical monitoring is often perceived as intruding into private spheres and violating individual intimacy, thereby provoking feelings of being permanently controlled [59, 117]. The acceptance of medical technology is a consequence of balancing the envisioned benefits against the perceived concerns in a dynamic process, influenced and shaped by a variety of individual and situational aspects [13]. Consequently, design approaches have to undergo a radical change by taking current societal trends into account [118]. User diversity, in terms of age, gender, social, and cultural factors, has to be systematically integrated into the development process in order to provide human-centered pervasive health technologies that truly meet the diverse requirements of their users. Studies show that older users face difficulties in learning and using new computer applications and have higher demands for usable interface designs [27, 37, 88]. Whenever interfaces are designed with the abilities of older users in mind (meeting the age-related decrease in sensory, motor, and cognitive abilities over the life span), the interaction of older users with technology is considerably improved and even able to match the performance of younger adults. Age-sensitive interaction concepts allow users with different ability levels to successfully interact with new technical applications. Consequently, only the integration of technical, personal, and societal requirements [50] can lead to truly personalized [22, 97], age-sensitive [24], and context-aware designs [7, 51].

1.5 Conclusion

A systematic inclusion of human perspectives into technical development is a crucial challenge for the design of future healthcare applications. Even though the idea of user-centered design has been formulated a long time ago, the development focus of technical products and services is still predominately on technical, economic and legal aspects. Especially in the field of medical services in which technical innovations led to numerous novel applications in the last years, it is of high importance to consider the requirements and the needs of patients—and in particular elderly and frail persons—in early phases of the design process. In this context, user acceptance is a delicate good which can be supported by integrating the intended users into the technical design process.

Only if needs, values, and individual usage habits are included into technology development, humane and human technology designs may result. Higher acceptance can be achieved by a conceptual device design that includes usability aspects and human values from the very beginning. In this way, a medical device can turn into something that patients are proud to wear or to possess, even for persons who have to cope with illness.

Consequently, the huge potential of pervasive health technologies in terms of daily support and medical care of the increasing number of seniors can only be leveraged if current technology design follows the demands raised by the need of incorporating human needs and values into its design development. This includes aspects of user diversity like age, gender, upbringing, culture and technology generation, but it also contains usage requirements arising from different application contexts. As such, addressing the fragile trade-off between the potential benefits of pervasive healthcare applications (ubiquitous support, reachability and universal access) and possible pitfalls (disregard of human values, violation of privacy and security) is of utmost importance.

References

1. Adam, A. (2002). Exploring the gender question in critical information systems. *Journal of Information Technology*, *17*, 59–67.
2. Akil, H., Martone, M. E., & Van Essen, D. C. (2011). Challenges and opportunities in mining neuroscience data. *Science*, *331*(6018), 708–712.
3. Alagöz, F., Calero Valdez, A., Wilkowska, W., Ziefle, M., Dorner, S., & Holzinger, A. (2010). From cloud computing to mobile internet, from user focus to culture and hedonism: The crucible of mobile health care and wellness applications. *IEEE 5th International Conference on Pervasive Computing and Applications*, *1*, 38–45.
4. Alagöz, F., Ziefle, M., Wilkowska, W., Calero Valdez, A. (2011). Openness to accept medical technology—a cultural view. In H. Holzinger, K.-M. Simonic (Eds.), *Human-Computer interaction: Information quality in eHealth* (pp. 151–170) LNCS 7058. Berlin, Heidelberg: Springer.
5. Alhakami, A. S., & Slovic, P. (1994). A psychological-study of the inverse relationship between perceived risk and perceived benefit. *Risk Analysis*, *14*, 1085–1096.

6. Allen, F. W. (1987). Towards a holistic appreciation of risk: The challenges for communicators and policymakers. *Science, Technology and Human Values*, *12*, 138–143.
7. Alnaniha, R., Ormandjievaa, O., & Radhakrishnana, T. (2014). A new methodology (CON-INFO) for context-based development of a mobile user interface in healthcare applications. In A. Holzinger, M. Ziefle, & C. Röcker (Eds.), *Pervasive health—state-of-the-art and beyond*. London: Springer.
8. Anandarajan, M., Igbaria, M., & Anakwe, U. (2000). Technology acceptance in the banking industry: A perspective from a less developed country. *Information Technology & People*, *13*(4), 298–312.
9. Anandarajan, M., Igbaria, M., & Anakwe, U. (2002). IT acceptance in a less-developed country: A motivational factor perspective. *International Journal of Information Management*, *22*(1), 47–65.
10. Arenas-Gaitána, J., Ramírez-Correab, P., & Rondán-Cataluñaa, F. (2011). Cross-cultural analysis of the use and perceptions of web-based learning systems. *Computers and Education*, *57*(2), 1762–1774.
11. Arning, K., & Ziefle, M. (2009). Different perspectives on technology acceptance: The role of technology type and age. In A. Holzinger & K. Miesenberger (Eds.), *Human-Computer interaction for eInclusion* (pp. 20–41). Berlin, Heidelberg: Springer.
12. Arning, K., Gaul, S., Ziefle, M. (2010). Same same but different. How service contexts of Mobile technologies shape usage motives and barriers. In G. Leitner, M. Hitz, A. Holzinger (Eds.), *HCI in work and learning, life and leisure*. *6th Symposium of the WG HCIandUE of the Austrian Computer Society*.
13. Arning, K., Kowalewski, S., & Ziefle, M. (2013). Health concerns Vs. mobile data needs: Conjoint measurement of preferences for mobile communication network scenarios. *International Journal of Human and Ecological Risk Assessment*. ISSN: 1080–7039. doi:10.1080/10807039.2013.838127
14. Bell, G., Hey, T., & Szalay, A. (2009). Beyond the data deluge. *Science*, *323*(5919), 1297–1298.
15. Berger, J. T. (1998). Cultural discrimination in mechanisms for health decisions: A view from New York. *Journal of Clinical Ethics*, *9*, 127–131.
16. Billings, A. G., & Moos, R. H. (1981). The role of coping re-sponses and social resources in attenuating the stress of life events. *Journal of Behavioural Medicine*, *4*(2), 139–157.
17. Böcker, M., & Schneider, M. (2014). E-Health applications for those in need: Making novel interaction technologies accessible. In A. Holzinger, M. Ziefle, & C. Röcker (Eds.), *Pervasive health—state-of-the-art and beyond*. London: Springer.
18. Bongers, A. J., Smith, S., Donker, V., Pickrell, M., & Hall, R. (2014). Interactive infrastructures—physical rehabilitation modules for pervasive healthcare technology. In A. Holzinger, M. Ziefle, & C. Röcker (Eds.), *Pervasive health—state-of-the-art and beyond*. London: Springer.
19. Busch, T. (1995). Gender differences in self-efficacy and attitudes toward computers. *Journal of Educational Computing Research*, *12*, 147–158.
20. Buxton, B., Hayward, V., Pearson, I., Kärkkäinen, L., Greiner, H., Dyson, E., et al. (2008). Big data: The next google. Interview by Duncan Graham-Rowe. *Nature*, *455*(7209), 8.
21. Campiniha-Bacote, J. (2002). The process of cultural competence in the delivery of health care services: A model of care. *Journal of Transcultural Nursing*, *13*(3), 181–184.
22. Caporusso, N., Trizio, M., & Perrone, G. (2014). Pervasive assistive technology for the deaf-blind—need, emergency and assistance through the sense of touch. In A. Holzinger, M. Ziefle, & C. Röcker (Eds.), *Pervasive health—state-of-the-art and beyond*. London: Springer.
23. Choon, Y.-Y. (2005). Cross-Cultural issues in human-computer interaction. In W. Karwowski (Ed.), *International Encyclopedia of Ergonomics and Human Factors* (Vol. 1, pp. 1063–1069). London: Taylor & Francis.
24. D'Angelo, L. T., Kreutzer, J. F., Neuhaeuser, J., Reimer, S., & Lueth, T. C. (2014). Personal assistive devices for elderlies: Executing activities of daily living despite natural aging-related changes. In A. Holzinger, M. Ziefle, & C. Röcker (Eds.), *Pervasive health—state-of-the-art and beyond*. London: Springer.

25. Dhar, V. (2013). Data science and prediction. *Communication of the ACM*, *56*(12), 64–73.
26. Durndell, A., & Zsolt, H. (2002). Computer self-efficacy, computer anxiety, attitudes towards the internet and reported experience with the internet, by gender, in an East European sample. *Computers in Human Behavior*, *18*, 521–535.
27. Ellis, D. R., & Allaire, J. C. (1999). Modeling computer interest in older adults: The role of age, education, computer knowledge and computer anxiety. *Human Factors*, *41*, 345–364.
28. Ericsson. (2011). *More than 50 Billion connected devices*. Ericsson, Stockholm, Sweden: White Paper.
29. Evans, D. (2011). *The internet of things: How the next evolution of the internet Is changing everything*. Cisco IBSG, San Jose, CA, USA: White Paper.
30. Feingold, A., & Mazella, R. (1998). Gender differences in body image are increasing. *Psychological Science*, *9*, 190–195.
31. Gaul, S., & Ziefle, M. (2009). Smart home technologies: Insights into generation-specific acceptance motives. In A. Holzinger & K. Miesenberger (Eds.), *Human-Computer interaction for eInclusion* (pp. 312–332). Berlin, Heidelberg: Springer.
32. Gefen, D., & Straub, D. (1999). Gender differences in the perception and use of e-mail: An extension to the technology acceptance model. *MIS Quarterly*, *21*, 389–400.
33. Grönvall, E., & Lundberg, S. (2014). On challenges designing the home as a place for care. In A. Holzinger, M. Ziefle, & C. Röcker (Eds.), *Pervasive health—state-of-the-art and beyond*. London: Springer.
34. Guo, B., Zhang, D., Wang, Z. (2011). Living with internet of things: The emergence of embedded intelligence. *Proceedings of the International Conference on Cyber, Physical, and Social Computing* (*CPSCom*, pp. 297–304). USA: IEEE Press.
35. Heidrich, F., Ziefle, M., Röcker, C., Borchers, J. (2011). Interacting with smart walls: A multi-dimensional analysis of input technologies for augmented environments. *Proceedings of the ACM Augmented Human Conference (AH'11)* (pp. 1–8).
36. Hey, T., Gannon, D., & Pinkelman, J. (2012). The future of data-intensive science. *Computer*, *45*(5), 81–82.
37. Himmel, S., Ziefle, M., Lidynia, C., Holzinger, A. (2013). Older users' wish list for technology attributes. A comparison of household and medical technologies. In A. Cuzzocrea, C. Kittl, D.E. Simos, E. Weippl, L. Xu (Eds.), multidisciplinary research and practice for information systems. *IFIP International Cross Domain Conference and Workshop on Availability, Reliability and Security* (pp. 16–27). *CD-ARES 2013, LNCS 8127* Heidelberg: Springer. ISBN: 978-3-642-40510-5.
38. Hofstede, G. (1980). *Cultures consequences*. Beverly Hills, CA: Sage.
39. Holzinger, A. (2011). Interacting with information: Challenges in human-computer interaction and information retrieval (HCI-IR). *Proceedings of the IADIS Multi-Conference on Computer Science and Information Systems (MCCSIS), Interfaces and Human-Computer Interaction* (pp. 13–17). Rome: IADIS.
40. Holzinger, A. (2012a). *Biomedical informatics: Computational sciences meets life sciences*. Norderstedt: BoD.
41. Holzinger, A. (2012). On knowledge discovery and interactive intelligent visualization of biomedical data: Challenges in human-computer interaction and biomedical informatics. In M. Helfert, C. Fancalanci, & J. Filipe (Eds.), *Proceedings of the International Conference on Data Technologies and Applications DATA 2012* (pp. 5–16). Italy: Rome.
42. Holzinger, A. (2013). Human-Computer interaction and knowledge discovery (HCI-KDD): What is the benefit of bringing those two fields to work together? In A. Cuzzocrea, C. K., D. E. Simos, E. Weippl, L. Xu (Eds.), *Multidisciplinary research and practice for information systems*, *LNCS 8127* (pp. 319–328). Heidelberg: Springer.
43. Holzinger, A., Ziefle, M., & Röcker, C. (2010). Human-computer interaction and usability engineering for elderly (HCI4AGING): Introduction to the special thematic session. In K. Miesenberger, et al. (Eds.), *ICCHP 2010, Part II LNCS 6180* (pp. 556–559). Heidelberg: Springer.

44. Holzinger, A., Stocker, C., Ofner, B., Prohaska, G., Brabenetz, A., & Hofmann-Wellenhof, R. (2013). Combining HCI, natural language processing, and knowledge discovery—Potential of IBM content analytics as an assistive technology in the biomedical domain. In A. Holzinger & G. Pasi (Eds.), *Human-Computer Interaction and Knowledge Discovery in Complex, Unstructured, Big Data, LNCS 7947* (pp. 13–24). Heidelberg: Springer.
45. Inglehart, R., & Klingemann, H. D. (2000). Genes, culture, democracy, and happiness. In E. Diener & E. M. Suh (Eds.), *Culture and subjective well-being* (pp. 165–183). Cambridge: MIT Press.
46. Institute of Electrical and Electronics Engineers, IEEE (2013). Top Trends for 2012. http://www.computer.org/portal/web/membership/13-Top-Trends-for-2013. Accessed 30 July 2013
47. Intel. (2009). *Rise of the Embedded Internet*. USA: Intel Corporation.
48. ITU. (2013). *The world in 2013: ICT facts and figures*. Telecommunication Development Bureau, International Telecommunication Union, Geneva, Switzerland: ICT Data and Statistics Division.
49. Iweins, C., Desmette, D., Yzerbyt, V., Stinglhamber, F. (2013). Ageism at work: The impact of intergenerational contact and organizational multi-age perspective. *European Journal of Work and Organizational Psychology, (ahead-of-print)* (pp. 1–16).
50. Jacobs, A., Duysburgh, P., Ongenae, F., Ackaert, A., Bleumers, L., & Verstichel, S. (2014). The innovation binder approach: A guide towards a social-technical balanced pervasive health system. In A. Holzinger, M. Ziefle, & C. Röcker (Eds.), *Pervasive health—state-of-the-art and beyond*. London: Springer.
51. Jiménez García, J., Romero, N., Keyson, D., & Havinga, P. (2014). An integrated patient-centric approach for situated research on total hip replacement: ESTHER. In A. Holzinger, M. Ziefle, & C. Röcker (Eds.), *Pervasive health—state-of-the-art and beyond*. London: Springer.
52. John, B. (2013). Patterns of ageism in different age groups. *Journal of European Psychology Students*, *4*(1), 16–26.
53. Kasugai, K., Ziefle, M., Röcker, C., Russell, P. (2010). Creating spatio-temporal contiguities between real and virtual rooms in an assistive living environment. In J. Bonner, M. Smyth, S. O' Neill and O. Mival (Eds.), *Proceedings of Create 10 Innovative Interactions* (pp. 62–67). Loughborough: Elms Court.
54. Kedia, B., & Bhagat, R. (1988). Cultural constraints on transfer of technology across nations. *Academy of Management Review*, *13*(4), 471–559.
55. Keogh, E., & Mansoor, L. (2001). Investigating the effects of anxiety, sensitivity and coping on the perception of cold pressor pain in healthy women. *European Journal of Pain*, *5*, 11–22.
56. Kleinberger, T., Becker, M., Ras, E., Holzinger, A., & Müller, P. (2007). Ambient intelligence in assisted living: Enable elderly people to handle future interfaces. *Universal Access in HCI, LNCS 4555*, 103–112.
57. Klessig, J. (1992). Cross-cultural medicine a decade later. The effect of values and culture on life-support decisions. *The Western Journal of Medicine*, *157*, 316–322.
58. Kreie, J., & Cronau, T. P. (1998). How men and women view ethics. *Communications of the Association for Computing Machinery*, *41*(9), 70–76.
59. Lahlou, S. (2008). Identity, social status, and face-keeping in the digital society. *Journal of Social Science Information*, *47*(3), 299–330.
60. Lahlou, S., Langheinrich, M., & Röcker, C. (2005). Privacy and trust issues with invisible computers. *Communications of the Association for Computing Machinery*, *48*(3), 59–60.
61. Leidner, D., & Kayworth, T. (2006). A review of culture in information systems research: Toward a theory of information technology culture conflict. *MIS Quarterly*, *30*, 2.
62. Leonhardt, S. (2006). Personal healthcare devices. In S. Mekherjee, et al. (Eds.), *Malware: Hardware technology drivers of ambient intelligence* (pp. 349–370). Dordrecht: Springer.
63. Lightbody, G., Galway, L., & McCullagh, P. (2014). The brain computer interface: Barriers to becoming pervasive. In A. Holzinger, M. Ziefle, & C. Röcker (Eds.), *Pervasive health—state-of-the-art and beyond*. London: Springer.

64. Maguire, M., & Osman, Z. (2003). Designing for older and inexperienced mobile phone users. In C. Stephanidis (Ed.), *Universal access in HCI: Inclusive design in the information society* (pp. 439–443). Mahwah, NJ: Lawrence Erlbaum.
65. Malinowski, M. (1996). Capitation, advances in medical technology, and the advent of a new Era in medical ethics. *American Journal of Law and Medicine*, *22*, 331–360.
66. Meeker, M., Wu, L. (2013). Internet Trends. http://www.kpcb.com/insights/2013-internet-trends. Accessed: 1 August 2013
67. Meyer, S., & Mollenkopf, H. (2003). Home technology, smart homes, and the aging user. In K. W. Schaie, H.-W. Wahl, H. Mollenkopf, & F. Oswald (Eds.), *Aging independently: Living arrangements and mobility*. New York: Springer.
68. Miller, S. M., Brody, D. S., & Summerton, J. (1988). Styles of coping with threat: Implications for health. *Journal of Personality and Social Psychology*, *54*, 142–148.
69. Mynatt, E. D., & Rogers, W. A. (2001). Developing technology to support the functional independence of older adults. *Ageing International*, *27*, 24–41.
70. Necheles, T. (1982). Standards of medical care: How does an innovative medical procedure become accepted. *The Journal of Law, Medicine and Ethics*, *10*, 15–18.
71. Nelson, T. (Ed.). (2004). *Ageism: Stereotyping and prejudice against older persons*. Cambridge: The MIT Press.
72. Pai, F.-Y., & Huang, K. (2011). Applying the technology acceptance model to the introduction of healthcare information systems. *Technological Forecasting and Social Change*, *78*(4), 650–660.
73. Palmore, E. (2001). The ageism survey first findings. *The Gerontologist*, *41*(5), 572–575.
74. Polanyi, M. (1974). Personal knowledge: Towards a post-critical philosophy. Nature Publishing Group.
75. Popper, K. R. (1996). *Alles Leben ist Problemlösen*. München, Zürich: Piper.
76. Renn, O., & Swaton, E. (1984). Psychological and sociological approaches to study risk perception. *Environment International*, *10*, 557–575.
77. Renn, O., Burns, W. J., Kasperson, J. X., Kasperson, R. E., & Slovic, P. (1992). The social amplification of risk: Theoretical foundations and empirical applications. *Journal of Social Issues*, *48*, 137–160.
78. Röcker, C. (2009a). *Design requirements for future and emerging business technologies: An empirical cross-cultural study analyzing the requirements for ambient intelligence applications in work environments*. Taunusstein: Dr. Driesen.
79. Röcker, C. (2009b). Ambient intelligence in the production and retail sector: Emerging opportunities and potential pitfalls. *Proceedings of the International Conference on Innovation, Management and Technology (ICIMT'09)*, May 27–29, 2009, Tokyo, Japan, 1393–1404.
80. Röcker, C. (2010a). Services and applications for smart office environments—a survey of state-of-the-art usage scenarios. *Proceedings of the International Conference on Computer and Information Technology (ICCIT'10)*, January 27–29, Cape Town, South, Africa, 387–403.
81. Röcker, C. (2010b). Chances and challenges of intelligent technologies in the production and retail sector. *International Journal of Business and Economic Sciences*, *2*(3), 150–161.
82. Röcker, C. (2010c). Information privacy in smart office environments: A cross-cultural study analyzing the willingness of users to share context information. In D. Tanier, O. Gervasi, V. Murgante, E. Pardede, & B. O. Apduhan (Eds.), *Proceedings of the International Conference on Computational Science and Applications (ICCSA'10), March 23–26, Fukuoka, Japan, LNCS* (Vol. 6019, pp. 93–106)., Springer-Verlag Germany: Heidelberg.
83. Röcker, C. (2011). Smart medical services: A discussion of state-of-the-art approaches. In: S. Thatcher (Ed.): *Proceedings of the International IEEE Conference on Machine Learning and Computing (ICMLC'11)*, Vol. 1, 334–338.
84. Röcker, C., & Etter, R. (2007). Social radio—a music-based approach to emotional awareness mediation. *Proceedings of the International Conferences on Intelligent User Interfaces (IUI'07)* (286–289) . New York, USA: ACM Press.
85. Röcker, C., Feith, A. (2009). Revisiting privacy in smart spaces: Social and architectural aspects of privacy in technology-enhanced environments. *Proceedings of the International*

Symposium on Computing, Communication and Control (ISCCC'09), October 9–11, 2009, Singapore, 201–205.
86. Röcker, C., Janse, M., Portolan, N., Streitz, N.A. (2005). User requirements for intelligent home environments: A scenario-driven approach and empirical cross-cultural study. *Proceedings of the International Conference on Smart Objects and Ambient Intelligence (sOc-EUSAI'05)*, October 12–14, Grenoble, France, ACM International Conference Proceeding Series, 121, 111–116.
87. Röcker, C., Ziefle, M., Holzinger, A. (2011). Social inclusion in AAL environments: Home automation and convenience services for elderly users. *Proceedings of the International Conference on Artificial Intelligence (ICAI'11)*, (Vol. 1, pp. 55–59) July 18–20, Las Vegas, NV, USA.
88. Rodger, J. A., & Pendharkar, P. C. (2004). A field study of the impact of gender and user's technical experience on the performance of voice-activated medical tracking application. *International Journal of Human-Computer Studies*, *60*, 529–44.
89. Rogers, Y. (2009). The changing face of human-computer interaction in the age of ubiquitous computing. In A. Holzinger and K. Miesenberger (eds.), *Human-Computer-Interaction and usability for e-Inclusion. LNCS 5889* (pp. 1–19). Berlin: Springer.
90. Schwarzer, R. (1994). Optimism, vulnerability, and self- beliefs as health-related cognitions: A systematic overview. *Psychology & Health*, *9*(3), 161–180.
91. Searight, H., & Gafford, J. (2005). Cultural diversity at the end of life: Issues and guidelines for family physicians. *American Family Physician*, *71*(3), 515–525.
92. Seo, K., Kim, J., Ryu, H., & Jang, S. (2014). RehabMaster: A Pervasive rehabilitation platform for stroke patients and their caregivers. In A. Holzinger, M. Ziefle, & C. Röcker (Eds.), *Pervasive health—state-of-the-art and beyond*. London: Springer.
93. Sharma, R., & Thomas, C. J. (2013). *Ageism: problems and prospects*. New Delhi: Akansha Publishing.
94. Shiode, N. (2004). When space shrinks—digital communities and ubiquitous society: Digitally united? A case study on the penetration of wireless and ubiquitous information technologies in Japan. *Proceedings of the Winter International Symposium on Information and Communication Technologies (WISICT'04)*, 1–6.
95. Smith, R. (2013). 5 Cloud Computing Trends For 2013. http://www.cloudtweaks.com/2013/05/cloud-computing-trends-security/. Accessed 30 July 2013
96. Srite, M., & Karahanna, E. (2006). The role of espoused national cultural values in technology acceptance. *MIS Quarterly*, *30*, 3.
97. Stokes, E. (2014). The ongoing development of a multimedia gaming module to aid speech, language and communication. In A. Holzinger, M. Ziefle, & C. Röcker (Eds.), *Pervasive Health - State-of-the-Art and Beyond*. London: Springer.
98. Straub, D., Keil, M., & Brenner, W. (1997). Testing the technology acceptance model across cultures: A three country study. *Information & Management*, *33*(1), 1–11.
99. Straub, D., Loch, K., & Hill, C. (2002). Transfer of information technology to the Arab world: A test of Cultural influence modeling. In M. Dadashuadeh (Ed.), *Information Technology Management in Developing Countries* (pp. 92–151). Hershey: IRM Press.
100. Streitz, N. A., Magerkurth, C., Prante, T., & Röcker, C. (2005). From information design to experience design: Smart artefacts and the disappearing computer. *ACM Interactions, Special Issue on Ambient Intelligence—New Visions of Human-Computer Interaction*, *12*(4), 21–25.
101. Tedre, M., Sutinen, E., Kähkönen, E., & Kommers, P. (2006). Ethnocomputing: ICT in cultural and social context. *Communications of the ACM*, *49*(1), 126–130.
102. Teo, T., & Su Luan, W. (2008). A cross-cultural examination of the intention to use technology between Singaporean and Malaysian pre-service teachers: an application of the TAM. *Educational Technology and Society*, *11*(4), 265–280.
103. Turner, K. J. (2014). Managing telehealth and telecare. In A. Holzinger, M. Ziefle, & C. Röcker (Eds.), *Pervasive health—state-of-the-art and beyond*. London: Springer.
104. Vaughan, E. (1993). Individual and cultural differences in adaptation to environmental risks. *American Psychologist*, *48*, 673–80.

105. Venkatesh, V., & Morris, M. (2000). Why don't men ever stop to ask for directions? Gender, social influence, and their role in technology acceptance and usage behavior. *MIS Quarterly*, *24*, 115–139.
106. Vlek, C., & Stallen, P. (1980). Rational and personal aspects of risk. *Acta Psychologica*, *45*, 273–300.
107. Waltisberg, D., Arnrich, B., & Tröster, G. (2014). Sleep quality monitoring with the smart bed. In A. Holzinger, M. Ziefle, & C. Röcker (Eds.), *Pervasive health—state-of-the-art and Beyond*. London: Springer.
108. Webster, A. (2002). Innovative health technologies and the social: Redefining health, medicine and the body. *Current Sociology*, *50*, 443–457.
109. Wilkowska, W., Ziefle, M. (2011). User diversity as a challenge for the integration of medical technology into future home environments. In M. Ziefle, C. Röcker (Eds.), *Human-Centred design of eHealth technologies. Concepts, methods and applications* (pp. 95–126). Hershey: IGI Global.
110. Wilkowska, W., & Ziefle, M. (2012). Privacy and data security in e-health: Requirements from users' perspective. *Health Informatics Journal*, *18*(3), 191–201.
111. Wilkowska, W., Gaul, S., & Ziefle, M. (2010). A small but significant difference—the role of gender on the acceptance of medical assistive technologies. In G. Leitner, M. Hitz, & A. Holzinger (Eds.), *HCI in work and learning, life and leisure USAB 2010, LNCS 6389* (pp. 82–100). Berlin, Heidelberg: Springer.
112. Wilkowska, W., Alagöz, F., & Ziefle, M. (2012). How age and country of origin impact the readiness to adopt e-Health technologies: An intercultural comparison. Work: A Journal of Prevention. *Assessment and Rehabilitation*, *41*, 2072–2080.
113. Wilson, M. (2002). Making nursing visible? Gender, technology and the care plan as script. *Information Technology and People*, *15*(2), 139–158.
114. Ziefle, M. (2002). The influence of user expertise and phone complexity on performance, ease of use and learnability of different mobile phones. *Behaviour and Information Technology*, *21*(5), 303–311.
115. Ziefle, M., & Bay, S. (2005). How older adults meet complexity: Aging effects on the usability of different mobile phones. *Behaviour and Information Technology*, *24*(5), 375–389.
116. Ziefle, M. Jakobs, E.-M. (2010). New challenges in human computer interaction: Strategic directions and interdisciplinary trends. *4th International Conference on Competitive Manufacturing Technologies*, South Africa: University of Stellenbosch, 389–398.
117. Ziefle, M., Röcker, C. (2010). Acceptance of pervasive healthcare systems: A comparison of different implementation concepts. In *Proceedings of the 4th International ICST Conference on Pervasive Computing Technologies for Healthcare* (PervasiveHealth'10), Munich, Germany, March 22–25, CD-ROM.
118. Ziefle, M., & Röcker, C. (2011). *Human-Centered design of e-health technologies: Concepts, methods and applications*. Niagara Falls: IGI Publishing.
119. Ziefle, M., Schaar, A.K. (2011). Gender Differences in Acceptance and Attitudes towards an Invasive Medical Stent. *Electronic Journal of Health Informatics*, 6, 1–18.
120. Ziefle, M., Schaar, A.K. (2014). Technology acceptance by patients: Empowerment and stigma. In J. V. Hoof, G. Demiris, E. Wouters (Eds.), *Handbook of smart homes, health care and well-being*. New York: Springer.
121. Ziefle, M., Röcker, C., Kasugai, K., Klack, L., Jakobs, E.-M., Schmitz-Rode, T., et al. (2009). eHealth—enhancing mobility with aging. In M. Tscheligi, B. de Ruyter, J. Soldatos, A. Meschtscherjakov, C. Buiza, W. Reitberger, N. Streitz, & T. Mirlacher (Eds.), *Roots for the future of ambient intelligence, adjunct Proceedings of the Third European Conference on Ambient Intelligence (Am I'09), November 18–21* (pp. 25–28). Salzburg: Austria.
122. Ziefle, M., Röcker, C., Wilkowska, W., Kasugai, K., Klack, L., Möllering, C., et al. (2011a). A multi-disciplinary approach to ambient assisted living. In C. Röcker & M. Ziefle (Eds.), *E-Health, Assistive technologies and applications for assisted living: Challenges and solutions* (pp. 76–93). Niagara Falls: IGI Publishing.

123. Ziefle, M., Röcker, C., Holzinger A. (2011b). Medical technology in smart homes: Exploring the user's perspective on privacy, intimacy and trust. T*he 3rd IEEE International Workshop on Security Aspects of Process and Services Engineering (SAPSE'11). 35th Annual IEEE Computer Software and Applications Conference*, July 18–22, 2011, Munich, Germany, pp. 410–415, ISBN: 978-1-4577-0980-7 DOI 10.1109/COMPSACW.2011.75.
124. Zimmer, Z., & Chappell, N. L. (1999). Receptivity to new technology among older adults. *Disability and Rehabilitation*, *21*, 222–230.