Human–Computer Interaction Series

Hannah R. Marston
Shannon Freeman
Charles Musselwhite *Editors*

Mobile e-Health

Springer

Human–Computer Interaction Series

More information about this series at http://www.springer.com/series/6033

Hannah R. Marston • Shannon Freeman
Charles Musselwhite
Editors

Mobile e-Health

Springer

Editors
Hannah R. Marston
Health & Wellbeing Priority Research Area,
School of Health, Wellbeing & Social
Care, Faculty of Wellbeing, Education
& Language Studies
The Open University
Milton Keynes, UK

Shannon Freeman
School of Nursing
University of Northern British Columbia
Prince George, BC, Canada

Charles Musselwhite
Centre for Innovative Ageing
School of Human and Health Sciences
Swansea University
Swansea, UK

ISSN 1571-5035
Human–Computer Interaction Series
ISBN 978-3-319-60671-2 ISBN 978-3-319-60672-9 (eBook)
DOI 10.1007/978-3-319-60672-9

Library of Congress Control Number: 2017954941

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Contents

Part I
Introduction

Chapter 1
An Introduction to the Potential for Mobile eHealth Revolution to Impact on Hard to Reach, Marginalised and Excluded Groups

Charles Musselwhite, Shannon Freeman, and Hannah R. Marston

Abstract eHealth is the use of technology to serve and promote health and wellbeing needs of a population. Mobile health is the use of wireless technologies to connect, communicate and promote this amongst different stakeholders within the population. This has great potential for improving the lives of all populations, especially those from traditionally marginalised or hard-to-reach groups, including those from developing countries, older people and those with chronic conditions for example. Mobile ehealth (mhealth) can link together healthcare practitioners and individuals better, provide information or offer feedback to improve self-awareness and manage health conditions individually and can offer games or challenges to encourage or motivate individuals to improve health. There are still concerns, however, that need addressing before mhealth can meet its potential, including, for example, security and privacy, information overload, emphasis on solving health issues rather than maintaining good health and not fully understanding how it fits into everyday lives of people, especially those not traditionally associated with technology such as older people. More research is needed on acceptability of such systems and developing standards and design and usability guidance. Overall mhealth can be seen as both enablers and disrupters, with the potential to revolutionise interactions people have about their own health but there is a need to reflect on the human and social issues surrounding such technology.

C. Musselwhite (✉)
Centre for Innovative Ageing, School of Human and Health Sciences, Swansea University, Swansea, UK
e-mail: c.b.a.musselwhite@swansea.ac.uk

S. Freeman
School of Nursing, University of Northern British Columbia, 3333 University Way, Prince George, BC, Canada

H.R. Marston
Health & Wellbeing Priority Research Area, School of Health, Wellbeing & Social Care, Faculty of Wellbeing, Education & Language Studies, The Open University, Milton Keynes, Buckinghamshire, UK

H.R. Marston et al. (eds.), *Mobile e-Health*, Human–Computer Interaction Series,
DOI 10.1007/978-3-319-60672-9_1

This collection draws together contemporary research and thinking from leading scholars in the field of mobile eHealth. Here eHealth in this book is defined by the World Health Organisation (WHO 2005) as "the cost-effective and secure use of information communication technologies (ICT) in support of health and health related fields, including health-care services, health surveillance, health literature, and health education, knowledge and research" (pp. 109).

eHealth is a broad term, which in the healthcare sector includes a broad scope of purposes ranging from purely administrative services across the spectrum of health-care service delivery (Health Canada 2010). Put simply, eHealth is the use of computing and associated technologies serving and promoting health and well-being needs. Mobile health (mHealth) is the use of mobile, wireless technologies to connect, communicate and promote this computing with the aim of supporting individual's health and well-being. The growing emphasis on mHealth programmes is reflected in the WHO's 2016 report of the third global survey on eHealth noting that over 90% of member states countries reported at least one mHealth initiative (WHO 2016).

Since the early 2000s, there has been unprecedented growth in the eHealth sector as the use of information and communication technology (ICT) expands across both high and low to middle income countries (WHO 2016). Traditional eHealth has been hugely advanced through improvements in mobile technologies and increased availability of applications. Continued growth of cellular networks across the globe fuels the rapid take-up of mHealth (WHO 2016). Seven billion people, 95% of the global population, now live in an area covered by a mobile cellular network (International Telecommunication Union 2016), comprising of mobile broadband networks of 3G or above each connecting 84% of the global population. However, there are large differences found between different countries and states. In high income countries around 90% of people have a mobile broadband contract, and in Singapore and Japan, the rate is over 100% (with people having over one subscription). In developing countries, the rate averages around 39%, but with great fluctuations – Africa remains the lowest continent of mobile subscriptions at around 20% network (International Telecommunication Union 2016).

People are beginning to engage with digital technologies such as Fitbits and mHealth apps to assist with self-monitoring and tracking one's health, physical activity and nutrition, in addition to managing chronic health conditions, such as diabetes or fall prevention (i.e. iStoppFalls). While research in this field is still in its infancy, digital care platforms available on the internet or through download to a digital device are growing in popularity. The notion of the quantified self (QS) may be increasingly realised through digital resources such as www.medhelp.org, a digital platform that partners with healthcare partners such as Merck and Fitbit to support patient engagement and deliver health solutions and drive changes in clinical outcomes to millions of users (see, e.g. www.medhelp.com/).

The use of digital games utilised for cognitive or physical rehabilitation in conjunction with the usability and accessibility issues is also relatively new. Hence, little is still known about the utility, use and best-design practices of these technologies for certain demographics. Although since 2008, research in the area of use and

best-design practices has grown enabling researchers to explore and understand the needs and requirements of older adults in the domain of games for health and digital gameplaying (Marston and Graner-Ray 2016; Marston 2012, 2013; De Schutter 2010; Nap et al. 2009; IJsselsteijn et al. 2007). In addition, research and thinking in this area stem from a variety of disciplines including public health, computer science, and human-computer interaction (HCI), psychology, sociology and gerontology, resulting in very different questions being addressed and different research frameworks being utilised.

The intention of this proposed edited book is to collectively bring together a series of works primarily associated with life-logging activities, mHealth apps and digital gaming across the lifespan. Since the turn of the twenty-first century, researchers have been exploring the possibilities of utilising commercial and purpose-built digital game hardware and software for primary use within health rehabilitation aimed at adults approximately 60–70 years. There remains a gap in understanding of the barriers and facilitators of eHealth technology use by older compared to younger cohorts. There has been little emphasis on expanding understanding of how older adults engage in life-logging activities via technology devices such as Fitbit or access online health resources to support self-care. Since the introduction of smartphones (e.g. iPhone), the popularity of mHealth apps amongst younger populations has grown exponentially, resulting in a variety of apps to enable users to self-monitor their health and integrate their day-to-day habits easier, for example, online purchasing (e.g. Amazon); women's health (e.g. monitor menstrual cycle, pregnancy); order and pay for transport (e.g. coach companies, taxi firms); online dating, social media and utilities (e.g. flashlight, calculator); download and read documents (e.g. Adobe, Microsoft Word); and access up-to-date current affairs (e.g. BBC News).

These are just some of the apps available and there are many more which have been specifically developed for towns and cities worldwide. Although the development and phenomenal take-up of smartphones have enabled the utility of mHealth apps to users across the lifespan, there is little published work associated to theoretical concepts, research methods and in-depth studies (e.g. feasibility, prospective and randomised control trials) focusing on the usability and accessibility of using apps, in addition to the accuracy and reliability of data collected over a period of time. Therefore, bringing together mHealth apps and ascertaining where in society these apps sit and whether users are gaining their full potential warrants further exploration and study.

The World Health Organisation (WHO) corporate strategy establishes the goals of building healthy populations and communities and combating ill health through the adoption of four strategic approaches:

- Reducing excess mortality, morbidity and disability, especially in poor and marginalised populations
- Promoting healthy lifestyles and reducing factors of risk to human health that arise from environmental, economic, social and behavioural causes

- Developing health systems that equitably improve health outcomes, respond to peoples' legitimate demands and are financially fair
- Developing an enabling policy and institutional environment in the health sector and promoting an effective health dimension to social, economic, environmental and development policy

It is important to stress that health and well-being must be viewed beyond simply as services delivered by the health sector alone. The contribution of other sectors is vitally for improving the health and well-being of the population.

The United Nation's (UN) global partnership for sustainable development, Agenda 21 emphasised many elements which are necessary for the integration of local and national health concerns into environment and development planning. These are (1) identification and assessment of health hazards associated with environment and development, (2) development of environmental health policy incorporating principles and strategies for all sectors responsible for development, (3) communication and advocacy of this policy to all levels of society and (4) a participatory approach to implementing health and environment programmes. The potential for eHealth and mHealth to help meet these priorities across the globe is exciting. Increased data collection and sharing of such data at a macro- and micro-level (e.g. life logging) can lead to better understanding and therefore early detection or avoidance of hazards and can help develop and maintain evidence-based environmental health policy. Such technology advances communication between different sectors and different users across society and helps foster more of a participatory approach to health and well-being, giving individuals more responsibility for their own health and well-being, supported by a variety of experts.

Mobile eHealth technologies have the potential to support the health and well-being of vulnerable and marginalised populations who traditionally have been more difficult to reach groups on the margins of the greater population. This edited collection will highlight how mobile eHealth technologies can support such groups who traditionally might be excluded or find it difficult to reach mainstream services. The main group concentrated upon is the older population. Ageing is a global phenomenon; society is ageing at a faster rate than ever. People are living longer and at the same time birth rates and infant mortality is at an all-time low in many countries. Across the globe we live in an ageing society.

Western countries especially are seeing a rapidly ageing society due to a combination of people living longer due to better health and social care and lower birth rates. This results in both a higher number and a higher percentage of people in their later years. There are now 840 million people over 60 across the world, representing 11.7% of the population. In 1950, there were only 384.7 million people aged over 60, representing only 8.6% of the global population (UN 2015).

Projections suggest there will be two billion people aged over 60, representing 21.2% of the global population by 2050 (UN 2015). The rate of increase in older people is faster in wealthier countries. For example, the United Kingdom (UK) will reach 25% of the population being over 60 by around 2030 (ONS 2015). The health of an ageing society is naturally of utmost importance as the prevalence of

chronic disease is increased. It is imperative that older people not only live longer but live well for longer, that they are healthy and have good quality of life, that they are not excluded from activity and that they stay connected to the things that matter to them.

On the face of it, it seems telehealth and telecare systems should be able to support individuals to remain independent and able to live at home longer without recourse to using services. But not only does the right technology need to be available and accessible to the right person at the right time in their preferred location of care but that it must also be provided in a safe and secure manner which meets legal standards and policies. As one may see from Part VI Privacy & Legal Requirements (which comprises of three contributions by Lynch and Fisk, Mantovani and Cristobal Bocos and Wiersinga), this may not be as straightforward as is hoped. We need to understand the specific detail of the in-person interaction between individual and health professional. When compared to traditional provision of face-to-face care, important questions arise including the following: Can telehealth provide the same or better level of care? Does provision of care through telehealth identify the same detail as in-person consultation does? Can eHealth web platforms and apps identify the nuances that in-person consultation can do? Above all, the question remains, how and when should it supplement or replace in-person consultation? The answer is, yet, we just do not have a strong enough evidence base to reliably know, and more research is needed to identify how eHealth may fit into practice within and across countries.

An example of where we are now, in terms of how mobile eHealth, can be seen in the prolific availability of apps available to support someone living with long-term chronic pain. Rosser and Eccleston noted in 2011 that in this case a person may have access to at least 111 different apps to support living with their pain. These range from passive systems that provide information (54% of them) to monitoring and tracking (24%) and interventions (17%); some provide linking with healthcare, some are individual, and some provide peer-to-peer support (Rosser and Eccleston 2011). Since 2011, one can only imagine the vast number of apps which would now be available given the vast expansion in digital app and eHealth technology. Faced with the plethora of apps, it can be overwhelming for a patient or even a health professional make the correct choice of which eHealth resource best fits the needs of the person.

Despite the abundance of available applications, the scientific evaluation of apps is scarce. Moreover, there are barriers to the use of mHealth for chronic pain management, which are similar for other conditions. Vardeh et al. (2013) identify (1) security and privacy concerns, (2) the burden of too much information (especially via sound and text), (3) an overwhelming amount of information, (4) an overemphasis on pain rather than exploring diversionary tactics, (5) poor compatibility with other records (e.g. medical records), (6) physical or cognitive restriction in using the device and (7) that costs may be increased rather than reduced. In this book, the chapter by Ruzic and Sanford (Chap. 2) examines this in more detail.

More research is not only needed on the efficacy of such systems but on the acceptability as well. Developing evidence-based standards, codesigning of apps

with people who would use them and having systematic design strategies start to order such a milieu of technology. This collection of papers deals with this; see Lynch and Fisk (Chap. 11), for example, on setting standards and Ruzic and Sanford on design strategies (Chap. 2), especially relating their new set of standards to people living with multiple sclerosis as they age.

Digital technology is often seen as a panacea for global health issues, not least in developing countries with dispersed communities and limited resources. Indeed, there are more mobile apps per head in Africa than any other low to middle income country outside of India. Successful examples include speeding up of early infant HIV diagnosis by turning around test results quicker in the SMART project Nigeria and improving access to health information and services amongst rural women and children in the Mobile Technology for Community Health (MOTECH) initiative with the Ghana Health Service. Access to healthcare varies considerably across different low to middle income countries and regions.

As a result, inequalities exist in provision healthcare across low to middle income countries. Generally, people living in urban locations have better access to healthcare than the rural areas. The dispersed nature of populations and healthcare in low to middle income countries have resulted in the World Health Organisation promoting eHealth projects aimed at crossing the physical accessibility to healthcare. As an example in Africa where inequalities are high, these include the Telemedicine Network for Francophone African Countries (RAFT), Access to Research in Health Programme, ePortuguese Network and Pan-African e-Network Project.

This collection of chapters can help to demystify the mobile eHealth revolution. It offers up a mirror which helps researchers, developers and society look at technological advances and identifies technology as the primary means of leading the mobile eHealth revolution. We need to pause and slow down the technocratic approach to allow for an evidence base to be developed to show whether the plethora of eHealth technology is assisting to improve the health and well-being of individuals in contrast to simply be a means of generating revenue for its creators. Chapters in this book will assist to support better understanding of how eHealth technology fits within society and within individual lives. It is paramount to reflect on whether technology enables its users to improve their daily lives, to function better collectively and individually.

We start this collection with Ruzic and Stanford (Chap. 2) who look at four different design strategies for involving older people in developing usability of technologies – universal design, design for ageing, universal usability and handheld mobile device interface design. All four have merits, but not one approach does everything. It is a case of choosing the right approach for the questions being asked or utilising the best parts of all four approaches. In bringing the best parts of each together, the integrative guidelines Universal Design Mobile Interface Guidelines (UDMIG) are proposed, and their refinement and applicability are discussed in the chapter.

The nature of mobile eHealth that allows personalisation and connectivity with other people fosters a perfect platform for developing support for people in the form of challenges or games. Across Europe the Interactive Software Federation of

Europe (ISFE) has reported digital gameplay across Europe to decrease as people age, with most gamers being in the youth categories (ISFE 2012). But there has been an increase in looking at older digital gamers (Musselwhite et al. 2016). Marston (2012, 2013) identified a series of rationales, pleasures and in-game perspectives as to why older adults would engage with games: a purpose, educational elements, goals, addressing real problems, gain knowledge, enjoyment, satisfaction and obstacles. For the game to be successful, the implementation of objectives, challenges, goals and rewards should be introduced over the duration of play. Malone (1980, 1982) and IJsselsteijn et al. (2007) suggest implementing varying and increasing levels of difficulty to facilitate this goal. Allowing users to build upon their skill and mastery is an important element of gaming. Offering users, the opportunity to complete different levels will enable users to build upon one's self-confidence and the skills needed (Malone 1980, 1982; Melenhorst 2002; IJsselsteijn et al. 2007).

Implementing specific content into a game has the potential to build upon ones' knowledge; therefore, learning enables users to enhance their skills, knowledge and personal achievement. Understanding the design requirements of older adults is one of the fundamental areas that need to be addressed and supported by the games industry and research and development projects for future development. Van Bronswijk (2006) states "active engagement of older adults in the design process is imperative to successful take-up of the technologies, bridging the generation-gap of young creative and older users" (pp. 184). Integrating older adults from the initial concept stage, continuing throughout the development and marketing processes, could enable industry and projects to learn and understand end user concerns. Integrating learning and educational elements could provide end users of all generations the ability to learn while playing and provide a purpose to gameplaying.

Combining a purpose within play will aid users to understand the end goal and objectives of the game. While combining a variety of levels of difficulty, challenges have the potential to aid the learning process, build upon self-confidence and keep the end users focused and engaged. Subsequently, providing a clear and positive feedback during play would enable users to build up their self-confidence and knowledge. There are four chapters addressing how far games can improve the health and well-being of older adults. Duplaa et al. (Chap. 6) note how most research on games and health have centred on the benefits of digital gameplay on computers and game consoles. They take the discussion a step further looking at the potential for mobile digital games in the health and well-being of older adults, specifically in terms of physical, mental and social interactions. There are two chapters giving further examples of gamification and health. Marston et al. (Chap. 7) introduce knowledge gleaned from the iStoppFalls programme on what type of games older people enjoy playing and how and why they play such games – what is their motivation to interact? What do they enjoy doing? What do they themselves get out of it? It's an important reminder not just to look at objective outcomes in relation to games but to look at interaction with games from the perspective of the older person themselves.

A further example is shown by Paczynski et al. (Chap. 5) examining how an interactive and immersive art programme called Splashboard can aid health and

well-being of participants living with one or more medical conditions including dementia, depression or recovery from stroke. The simplicity of the technology is key; the art is created on a video screen of the real world, simply by moving the body in different ways to create a "painting". Naturally, the nature of such technology improves physical activity but also important is the improvements in immersion and enjoyment when creating with technology such as this. Sometimes, immersion, flow and enjoyment of creating art are the motivation for physical activity, thus improving health and well-being without it feeling like a chore. Again, it seems common sense but amazing how many times enjoyment is overlooked as being important in relation to motivating people to improve their health and well-being.

Holz Ivory et al. (Chap. 9) explore and discuss a variety of research which has specific focus within the health domain and how digital games can have effect on the respective participants in the studies. Furthermore, the respective authors (Holz Ivory and Ivory) suggest developmental approaches and methods for future work in this domain in a bid to guide future research in the area of gaming and health research in particular across older population.

Big data is often championed and heralded as helping to improve society. Data is collected and now shared in many different health and care situations. This data can be highly personalised and used at individual and collective levels. One growing trend associated with this is the quantified self where mobile devices can collect data about our daily lives. Simple and relatively cheap devices can now include collection of all sorts of data from steps taken, distance travelled, sleep patterns to heart rate and calorie intake. A little more complex and with some direct user input can see people add their own thoughts or feelings to the data, creating life-logging e-diary technologies. How might these systems be used to improve health and well-being of people? Again, especially people on the margins or those for whom technology is not always seen as second nature. These elements are covered in terms of philosophies of the self in Sacremento and Wanick's Chap. 3 and then applicability of this to keeping older people independent and at home viewed in DeMaeyer's contribution (Chap. 4). How this changes the behaviour through changes in understanding of the body is described.

Technologies are increasingly being viewed as a means to keeping people independent and keeping people from accessing services unnecessarily. Technology can reduce the geographical distance required to travel to healthcare providers, surgeries, hospitals and outpatient clinics, for example. Technology can compile health monitoring of individuals and send them to healthcare professionals without the need for the individual or the healthcare professional to travel. Consultations can happen in the home with doctors and other healthcare practitioners through live video links. Reduction in unnecessary visits and keeping people from having to access healthcare is seen as the positive outcome. The reality is not as simple as it might seem, as Di Fiore and Ceschel (Chap. 10) remind us in their chapter of technologies supporting home care. Home care is a complex task, often supporting someone with co-morbidities and a variety of needs. The chapter reminds us to start with the person and their needs and requirements first and foremost, stressing how much of the research in the field is on the technological innovation itself rather than

its interaction with people. The coordination of care is vital in this context but again is typically seen as secondary to the technology itself, so again there is a need to involve users of the technology, the support workers, in the development of such technology.

Mobile eHealth has the potential for revolutionising how people understand and interact with their own health and their own bodies. They are both enablers and disrupters as pointed out by Lynch and Fisk (Chap. 11). There is the decentralisation of medicine, a reduction in top-down nature of medical provision and a wider potential for sharing data. Ultimately it has potential to change individual's own health behaviour. Naturally, this has very strong ethical and governance implications. Who owns such data when it is ultimately the person's own behaviour, yet it is only interpreted through interaction with the device and sometimes additional interaction with health professionals? What are the security issues; what if there are breaches of data? What are the privacy issues? These are again covered by Lynch and Fisk (Chap. 11).

Given that much mobile eHealth appears as apps, Mantovani and Cristobal Bocos (Chap. 12) and Wiersinga (Chap. 13) cover the legal issues surrounding such mobile apps. Medical devices are clearly covered by law that enables them to be fit for purpose and have undergone rigorous testing, but apps fit a grey area just outside of this and can be developed and sold as a non-medical device meaning they are not subject to such stringent checks and laws. There is much debate about top-down regulation vs bottom-up innovation, with new laws perhaps being needed to fit such technologies.

This is an exciting time for health and technology. Potential issues with individual ownership of and individual responsibility for health can be resolved with mobile eHealth. They can be of benefit to groups who are marginalised or excluded from regular health and complement existing health services and support. But, it is also a dangerous time. Technology continues to advance quickly, while the research evidence to support its use and philosophical debate surrounding the value of its use have not yet caught up to highlight the relative merits and dangers of such apps and how individuals and society can gain best outcomes from them and maximise their use to facilitate understanding and improvement in health behaviours. This book aims to provide evidence to begin to plug this gap, drawing on expertise in the field to pause and reflect on the social, philosophical and human issues surrounding the accelerated development of mobile eHealth, telehealth and abundance of health and well-being apps.

References

De Schutter B (2010) Never too old to play: the appeal of digital games to an older audience. Games Culture 6(2):155–170

Health Canada (2010) Ehealth. Available at http://www.hc-sc.gc.ca/hcs-sss/ehealth-esante/index-eng.php. Accessed 15 June 2017

IJsselsteijn W, Nap HH, de Kort Y, Poels K (2007) Digital game design for elderly users. In: Proceedings of the 2007 conference on future play. ACM, Toronto, pp 17–22

Interactive Software Federation of Europe (ISFE) (2012) Videogames in Europe: 2012 Consumer Study. Retrieved from http://www.isfe.eu/industry-facts/statistics. Accessed 15 June 2017

International Telecommunications Union (2016 ICT facts and figures 2016. ITU, Geneva. Available at http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2016.pdf. Accessed 15 June 2017

Malone TW (1980) What makes things fun to learn? Heuristics for designing instructional computer games. In: Proceedings of the 3rd ACM SIGSMALL symposium and the first SIGPC symposium on small systems. ACM, New York, pp 162–169. doi:10.1145/800088.802839

Malone TW (1982) Heuristics for designing enjoyable user interfaces: lessons from computer games. In: Proceedings of the 1982 conference on human factors in computing systems. ACM, New York, pp 63–68. doi:10.1145/800049.801756

Marston HR (2012) Older adults as 21st century game designers. Comput Games J Whitsun 1(1):90–102

Marston HR (2013) Design recommendations for digital game design within an ageing society. J Educ Gerontol 39(2):103–118

Marston HR, Graner-Ray S (2016) Older women on the game: understanding digital game perspetives from an ageing cohort. In: Nierling L, Dominguez Rue E (eds) Ageing and technology: perspectives from the social sciences. Transcript-Verlag, Bielefeld, pp 67–92

Melenhorst AS (2002) Adopting communication technology in later life: the decisive role of benefits. Unpublished doctoral dissertation, Eindhoven University of Technology, Eindhoven, The Netherlands

Musselwhite C, Marston HR, Freeman S (2016) From needy and dependent to independent Homo Ludens: exploring digital gaming and older people. Games Cult 11(1–2):3–6

Nap HH, de Kort YAW, IJsselsteijn WA (2009) Senior gamers: preferences, motivations and needs. Geron 8(4):247–262

Office for National Statistics (ONS) (2015) Annual mid-year population estimates for the UK. Available at https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/annualmidyearpopulationestimates/latest. Accessed 15 June 2017

Rosser BA, Eccleston C (2011) Smartphone applications for pain management. J Telemed Telecare 17:308–312

United Nations (UN) (2015) World population ageing. United Nations, New York. Available at http://www.un.org/en/development/desa/population/publications/pdf/ageing/WPA2015_Report.pdf. Accessed 15 June 2017

Van Bronswijk JEMH (2006) Persuasive GERONtechnology: an introduction. Springer, Berlin/Heidelberg, pp 183–186. Copyright ©2006

Vardeh D, Edwards R, Jamison RN, Eccleston C (2013) There's an app for that: mobile technology is a new advantage in managing chronic pain. Clinical Updates, Pain, Dec, pp 1-7

WHO (World Health Organization) (2005) Resolution WHA58.33. Sustainable health financing, universal coverage and social health insurance. In: Fifty-eighth World Health Assembly, Geneva, 16–25 May 2005. Resolutions and decisions annex. World Health Organization, Geneva. Available at http://apps.who.int/medicinedocs/documents/s21475en/s21475en.pdf. Accessed 15 June 2017

WHO (World Health Organization) (2016) Global diffusion of eHealth: making universal health coverage achievable. Report of the third global survey on eHealth. World Health Organization, Geneva. Available at http://apps.who.int/iris/bitstream/10665/252529/1/9789241511780-eng.pdf?ua=1. Accessed 15 June 2017

Charles Musselwhite is an associate professor, at the Centre for Innovative Ageing, Swansea University, and heads-up the groups Environments and Ageing research strand. He is Operational Director of the Centre for Ageing and Dementia Research (CADR), an initiative to develop and enhance research, policy and practice for older people across Wales. He has a particular interest in ageing, travel and transport, addressing technological, environmental, health and sustainability contexts of transportation and built environment studies. Prior to joining CIA, his research addressing ageing and transport spans four interconnected areas including (1) attitudes to transport and travel; (2) older people, travel behaviour change and health and wellbeing; (3) giving up driving for later life; and (4) road user safety and ageing. Dr. Musselwhite has been involved in a variety of other built environment, mental health and shipping projects. Charles has advised the Parliamentary Advisory Council for Transport Safety on older people's transport issues. He is a member of the British Society of Gerontology. His research on older people and their travel and driving behaviour has involved several invited international and national presentations at conferences and invited presentations to the House of Commons and the House of Lords. He has appeared on BBC TV and UK and Swedish radio stations on the subject.

Shannon Freeman is an assistant professor in the School of Nursing at the University of Northern British Columbia, co-president of the British Columbia Psychogeriatric Association, current vice president of the International Association on Geriatrics and Gerontology Coalition of Student Organizations and an interRAI Canada researcher. Dr. Freeman's research interests focus on the health and wellbeing of vulnerable populations with current research projects in the areas of gerontechnology, mental health and wellbeing of older adults and First Nations Elders and long-term care. She is a director of the Prince George Hospice Society and also takes an active role in research examining hospice palliative and end-of-life care.

Hannah R. Marston is a research fellow, in the Health and Wellbeing Priority Research Area (http://healthwellbeing.kmi.open.ac.uk/) in the School of Health, Wellbeing and Social Care, at The Open University, UK. In March 2017, Dr. Marston organized the first digital health and wellbeing symposium as lead of the Digital Health and Wellbeing Special Interest Group in the Health and Wellbeing Priority Research Area. The event was attended by external academics from across the UK and comprised of several external speakers and a panel discussion. She is currently organizing the 2nd Digital Health and Wellbeing conference to be held between 1–3 May, 2018, at The Open University campus. Hannah has published over 20 journal papers and 5 book chapters and currently serves on two editorial boards. Previously, Dr. Marston has worked internationally undertaking fixed-term positions in Germany as a research scientist on the iStoppFalls EU project at the Institute of Movement and Sport Gerontology at the German Sport University Cologne and in Canada as post-doctoral fellow at the University of Waterloo. Hannah interests are multi-cross disciplinary and include digital games, gender, ageing, lifespan, gamification, technology use and health.

Part II
mHealth Apps QS

Chapter 2
Universal Design Mobile Interface Guidelines (UDMIG) for an Aging Population

Ljilja Ruzic and Jon A. Sanfod

Abstract As people age, many of them experience decline in both health and function, which can negatively impact their use of and interaction with user interfaces. Four of the most widely accepted strategies for the design of user interfaces for an aging population and individuals with functional limitations were analyzed as part of this project: universal design (UD), design for aging (DfA), universal usability (UU), and guidelines for handheld mobile device interface design (MID). Analysis of the guidelines suggested that none of the four strategies alone were sufficiently comprehensive and inclusive enough to meet the range and diversity of usability needs of older adults within the environment of mobile touch screen interfaces. Based on the four strategies, a set of integrative guidelines, universal design mobile interface guidelines (UDMIG), were proposed to ensure usability of mobile eHealth devices by older adults. This chapter reports the continued development, refinement, and extension of the first version of the guidelines into UDMIG v.2.0, a more robust and inclusive set of design guidelines.

2.1 Introduction

Technology use among the aging population is growing and becoming more widespread (Fisk et al. 2012). However, with increased age many individuals experience decreased ranges and levels of abilities, such as vision, hearing, haptics, cognition, and dexterity, which can negatively impact their use of and interaction with user interfaces. Typical user interface problems include misunderstanding of general icons, long task completion times, poor task performance, errors, difficulty reading text due to small font size and poor color contrast, and confusion associating inputs with outputs (Becker 2004; Bederson et al. 2003; Chadwick-Dias et al. 2003). Nevertheless, these problems can be overcome by accommodating the wide range

L. Ruzic (✉) • J.A. Sanfod
The Center for Assistive Technology and Environmental Access, CATEA, Georgia Institute of Technology, Atlanta, GA, USA
e-mail: ljilja@gatech.edu; jon.sanford@coa.gatech.edu

H.R. Marston et al. (eds.), *Mobile e-Health*, Human–Computer Interaction Series,
DOI 10.1007/978-3-319-60672-9_2

of sensory perception, motor, communication, and mental needs into the design of the user interfaces (Morrell 2001).

Various design strategies are often used to address usability issues of interfaces by older adults and others with functional limitations. Four of the most commonly applied strategies include universal design (UD), design for aging (DfA), universal usability (UU), and guidelines for handheld mobile device interface design (MID). The four sets of existing guidelines were analyzed to determine their applicability to the design of mobile eHealth interfaces for older adults. Analysis of the guidelines suggested that none of the four strategies alone were sufficiently comprehensive and inclusive enough to meet the range and diversity of usability needs of older adults within the environment of mobile interfaces. To address these usability needs and reconcile inconsistencies among the four strategies, an initial set of integrative guidelines, universal design mobile interface guidelines (UDMIG), was proposed to ensure usability of mobile eHealth devices by older adults (Kascak et al. 2014). This chapter reports the continued development, refinement, and extension of those guidelines into UDMIG v.2.0, which is a more robust and inclusive set of design guidelines.

2.2 Four Design Strategies for Usability by Older Adults

Four of the most widely accepted strategies for the design of user interfaces for aging population and individuals with functional limitation were analyzed as part of this project: UD, DfA, UU, and MID. UD (Mace 1988) is a strategy that supports the diverse ranges and combinations of abilities and limitations that characterize the aging population. The purpose of UD is to design physical environments (e.g., buildings, spaces, products, graphics) for everyone and, by doing so, to overcome the barriers to usability that come with aging (Law et al. 2008). In contrast to UD's "design-for-all" approach, DfA (Nichols et al. 2006) specifically focuses on the design of user interfaces based on the needs and functional limitations of older adults. DfA is a strategy that explores the factors that constrain the use of products and user interfaces by older adults, as well as aspects of human-computer interface design that accommodate older users with age-associated disabilities and limitations (Zajicek 2001). Like UD, UU focuses on usability and inclusivity of all users. However, unlike UD, the domain of UU is information and communication interfaces (Shneiderman 1986). It consists of the eight guidelines, called the Eight Golden Rules of Interface Design. Finally, MID (Gong and Tarasewich 2004) are based on UU but are extending its application to interfaces on mobile and touchscreen platforms.

2.2.1 Universal Design

UD was defined by Mace in 1988 as design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design (Mace 1988). The purpose of UD is design of usable and equitable environments, products, and interfaces by reducing their complexity and minimizing individuals' reliance on their physical and cognitive capabilities in interacting with them (Universal Design Policy 2001). UD is an integral component of everyday design, considering users' ranges and combinations of abilities from the beginning of the design process (Ruptash 2013; Sanford 2012). As a result, UD creates environments, products, and interfaces that any person, regardless of cognitive and physical impairments, can use and access. It advocates for usable design by the greatest number of people, addressing a wider range of limitations and combinations of limitations that one might have (Falls Among Older Adults 2013).

To promulgate UD, 7 principles and 30 associated design guidelines were developed by a team of designers at NC State University (Connell et al. 1997) (see Table 2.1).

2.2.2 Design for Aging

DfA is a tool that not only articulates the problems that must be considered when designing systems, products, and environments for older adults but also provides design guidelines for addressing those problems (Fisk et al. 2009). DfA consists of the 52 design guidelines, grouped into six categories (see Table 2.2) that cover the factors that constrain the use of user interfaces by older adults, as well as aspects of human-computer interface design that accommodate older users with age-associated disabilities and limitations (i.e., memory, cognitive, hearing, visual, dexterity, and physical impairments) (Zajicek 2001).

2.2.3 Universal Usability

To extend UD beyond the physical environment and make it applicable to information and communication technology (ICT), UU was developed to make ICT interfaces usable and accessible by all people, with and without disabilities (Meiselwitz et al. 2010). Shneiderman (2000) believed that UU would be pervasive, enabling more than 90% of all households to be successful users of information and communications services at least once a week. To promote UU, Shneiderman and colleagues developed the *Eight Golden Rules of Interface Design* (see Table 2.3) applicable to most interactive systems to enable the widest range of users to benefit from information and communication services (Shneiderman and Plaisant 1987).

Table 2.1 The principles of universal design©

Principle one: Equitable use
The design is useful and marketable to people with diverse abilities
1a. Provide the same means of use for all users: identical whenever possible; equivalent when not
1b. Avoid segregating or stigmatizing any users
1c. Provisions for privacy, security, and safety should be equally available to all users
1d. Make the design appealing to all users
Principle two: Flexibility in use
The design accommodates a wide range of individual preferences and abilities
2a. Provide choice in methods of use
2b. Accommodate right- or left-handed access and use
2c. Facilitate the user's accuracy and precision
2d. Provide adaptability to the user's pace
Principle three: Simple and intuitive use
Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level
3a. Eliminate unnecessary complexity
3b. Be consistent with user expectations and intuition
3c. Accommodate a wide range of literacy and language skills
3d. Arrange information consistent with its importance
3e. Provide effective prompting and feedback during and after task completion
Principle four: Perceptible information
The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities
4a. Use different modes (pictorial, verbal, tactile) for redundant presentation of essential information
4b. Provide adequate contrast between essential information and its surroundings
4c. Maximize "legibility" of essential information
4d. Differentiate elements in ways that can be described (i.e., make it easy to give instructions or directions)
4e. Provide compatibility with a variety of techniques or devices used by people with sensory limitations
Principle five: Tolerance for error
The design minimizes hazards and the adverse consequences of accidental or unintended actions
5a. Arrange elements to minimize hazards and errors: most used elements, most accessible; hazardous elements eliminated, isolated, or shielded
5b. Provide warnings of hazards and errors
5c. Provide fail-safe features
5d. Discourage unconscious action in tasks that require vigilance
Principle six: Low physical effort
The design can be used efficiently and comfortably and with a minimum of fatigue
6a. Allow user to maintain a neutral body position
6b. Use reasonable operating forces
6c. Minimize repetitive actions
6d. Minimize sustained physical effort

(continued)

Table 2.1 (continued)

Principle seven: Size and space for approach and use
Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility
7a. Provide a clear line of sight to important elements for any seated or standing user
7b. Make reach to all components comfortable for any seated or standing user
7c. Accommodate variations in hand and grip size
7d. Provide adequate space for the use of assistive devices or personal assistance

Source: Connell et al. 1997. *The Principles of Universal Design*

Table 2.2 Design for aging categories

1. *Guidelines for visual presentation of information* secure required visual information for aging population, focusing on adequate levels of illumination and improved conditions for visual perception, increasing sizes, brightness, and contrast of visual objects (e.g., text, images, icons), isolating messages from other message channels, keeping consistent positioning of target items, and engaging alternative sensory systems for users who have serious visual impairments
2. *Guidelines for auditory presentation of information* help ensure that older adults receive needed auditory information, with focus on making speech more intelligible, on avoiding compressed and speeded speech, on using context to interpret speech (e.g., good structure in written and spoken texts, videoconferencing), on using other sensory modalities, and on improving the efficacy of warning signals
3. *Guidelines for haptic presentation of information* assist with increasing the quality of interaction with technology user interfaces while using the haptic processing and concentrating on the use of vibration to signal events and a choice of vibration frequency
4. *Guidelines for the design of input devices* help with user interaction with input devices by minimizing the number of steps of the process as well as the number of controls, providing the consistency of the layout control elements, designing for expectations or affordances (visual elements that suggest function), and providing alternative ways to navigate with input devices
5. *Guidelines for the design of output devices* focus on specific issues related to devices and to visual and auditory displays, such as choosing the type of display and the angle from which the display is read, shielding displays in outdoor environments, effectively presenting the important and warning information, and providing the tactile output devices for simple signaling
6. *Guidelines for effective interface design* address the human-computer interface problems related to menu designs, display layouts, system navigation, information organization, error recovery, compatibility, and design of help systems to accommodate older adults' expectations about how the system works and to ensure their goals match how the system functions

Source: Fisk et al. (2009)

2.2.4 Handheld Mobile Device Interface Design

To accommodate the growing number of mobile devices, the MID were developed by Gong and Tarasewich (2004) based on the Eight Golden Rules of Interface Design. Among the 15 design guidelines (see Table 2.4), the first four mirror rules 1, 3, 4, and 7 of the Eight Golden Rules of UU, while the other four are modified versions of the remaining four Golden Rules to fit the mobile environment. The

Table 2.3 Eight Golden Rules of Interface Design

1. *Strive for consistency*
Consistent sequences of actions are required in similar situations, and identical terminology should be used whenever possible
2. *Cater to universal usability*
The needs of diverse users including novices, experts, users of all age ranges, and users with disabilities need to be recognized
3. *Offer informative feedback*
For frequent and minor user actions, there should be modest system feedback, whereas for infrequent and major actions, the response should be more substantial
4. *Design dialog to yield closure*
Sequences of actions should be organized into groups with a beginning, middle, and end, with an informative feedback at the completion of a group of actions
5. *Prevent errors*
The system should be designed such that users cannot make serious errors, and if a user makes an error, the interface should detect the error and offer simple, constructive, and specific instructions for recovery
6. *Permit easy reversal of actions*
As much as possible, actions should be reversible
7. *Support internal locus of control*
Experienced users need to feel they are in charge of the interface and that the interface responds to their actions
8. *Reduce short-term memory load*
Interfaces in which users must remember information from one screen and then use that information on another screen should be avoided

Source: Shneiderman and Plaisant (1987)

additional seven guidelines address the unique characteristics of the mobile interface environment.

2.3 Comparison of the Four Design Strategies

The limitations older adults have can vary not only among individuals but within individuals over the course of a day, from day to day, and over time (Sanford 2012). Among the four, DfA is the only population-specific (i.e., a focus on older adults) strategy. However, more importantly, it is also the only strategy that explicitly links individuals' needs and abilities to design solutions. As such, it provides both an understanding of *what* the functional problems of older adults are and guidance on *how* design can be used to solve those problems. This person-environment fit approach not only provides an understanding of *why* interface design needs to be different to be usable by older adults but also the tools to create unique and innovative interfaces without relying on a rigid set of prescriptive rules.

In contrast to DfA, the other three design strategies address design for all users, including those with and without functional limitations. As such, these strategies

Table 2.4 Guidelines for handheld mobile device interface design

1. *Enable frequent users to use shortcuts*
Reduce the number of operations needed to perform regular (i.e., repetitive) tasks because time is often more critical to a mobile device user
2. *Offer informative feedback*
For every operator action, provide substantial and understandable system feedback
3. *Design dialogs to yield closure*
Organize sequences of actions into groups with a beginning, middle, and end, with an informative feedback at the completion of a group of actions
4. *Support internal locus of control*
Provide the interface that responds to user's actions, so that they feel in charge of the system
5. *Consistency*
Provide the same "look and feel" (elements of mobile interfaces) across multiple platforms and devices and device-independent input/output methodologies
6. *Reversal of actions*
Ensure that mobile applications rely on network connectivity as little as possible
7. *Error prevention and simple error handling*
Ensure that nothing potentially harmful is triggered by too simple operation (e.g., power on/off)
8. *Reduce short-term memory load*
Provide interface that relies on recognition of function choices instead of memorization of commands and uses different modalities (e.g., sound) to convey information where appropriate
9. *Design for multiple and dynamic contexts*
Configure the output to users' needs and preferences (e.g., text size, brightness), allow single- and no-handed operation, and ensure that the application adapts itself automatically to the user's current environment
10. *Design for small devices*
Provide word selection instead of requiring text input
11. *Design for limited and split attention*
Provide sound and tactile output options
12. *Design for speed and recovery*
Stop, start, and resume an application with little or no effort
13. *Design for "top-down" interaction*
Present high levels of information and let users decide whether or not to retrieve details
14. *Allow for personalization*
Provide users the ability to change settings to their needs or liking
15. *Design for enjoyment*
Design visually pleasing and fun as well as usable interfaces

Source: Gong and Tarasewich (2004)

propose a universal usability approach to everyday design. In addition, all three focus solely on how to design, without linking design to individuals' needs and abilities. Therefore, while these guidelines may instill a sense of what to design for universal usability, without an understanding of why, it is difficult to develop designs that will actually achieve that goal.

Among all four strategies, UD is the only one that does not focus on interface design, having been developed primarily for the physical environment. As a result,

adaptation and addition of some of the guidelines would be necessary to accommodate design for the interactive mobile environment. UU originally focused on access for users with disabilities. However, over time, it was expanded to include older and younger adults, users with slow network connections, small screens, no screens, and other limiting technologies (Shneiderman 2003). Of greater relevance here, UU was initially developed for desktop applications, not for mobile interfaces. Therefore, like UD, UU only partially supports mobile interface design and would require adaptation to provide full guidance for mobile applications. Finally, while MID are an adaptation and extension of some of the UU guidelines for mobile and touchscreen interfaces, these guidelines fall short of accommodating the multiple and combinations of limitations experienced by older adults.

Individually, none of the four strategies are sufficiently comprehensive or inclusive within a context of mobile eHealth interfaces for the aging population. However, taken together, the four strategies provide a complete platform for a more inclusive set of guidelines. The process and outcome of integrating the four strategies into a comprehensive, inclusive set of design guidelines for interactive mobile interfaces for the aging population are detailed below.

2.4 UDMIG v2.0

The first version of the guidelines, UDMIG v1.0, previously reported by Kascak et al. (2015), used the seven principles of UD as the baseline to which particular components of the other three sets of guidelines were added. However, this approach of adding a few guidelines to the UD principles was too simplistic and did not resolve the inconsistencies between UD's origins in the physical environment and language that needed to focus more on the digital environment. Moreover, because the four sets of guidelines included both prescriptive and performance-based approaches, sometimes within the same set of guidelines, the language and level of specificity of the original guidelines included in UDMIG v1.0 were inconsistent. Finally, UDMIG v1.0 failed to incorporate the person-environment interaction approach that was the unique contribution of DfA. As a result, the UDMIG guidelines were further developed within a framework based on the two organizing principles: a broader, more basic person-environment (P-E) fit model (Lawton and Nahemow 1973) and the guideline approach (i.e., prescriptive vs. performance based).

Person-Environment Fit

The person-environment (P-E) fit model (Lawton and Nahemow 1973) defined the degree to which individual and environmental characteristics match to promote healthy aging. The P-E fit model examined the match or fit between a person's ability and the demands of the environment. Barriers in the environment cause different ranges and quantities of usability problems depending on an individual's ability (Iwarsson and Ståhl 2003). When considering mobile devices, usability is achieved

when there is a match between a person's ability and the design of the interface. In UDMIG v.2.0, the person component is a part of all the guidelines in the description of how to accommodate people with different abilities. The fit component includes those guidelines that describe the design of the touchscreen mobile interface as a whole, as well as those that guide the design of the specific features of the mobile touchscreen interface with which users interact. These include both the context, which pertains to the design of the overall interface, and the design feature, which guides the design of the characteristics of the specific features. The environment component acknowledges the space requirements and context of use. It represents the larger environment that provides the context of interface use (e.g., lighting and glare). For purposes of this chapter, only the fit component will be addressed.

Guideline Approach

Guidelines in UDMIG v2.0 were also categorized as prescriptive or performance. Whereas the objective of both prescriptive and performance guidelines is to achieve usable design outcomes, they do so in very different ways. Prescriptive guidelines focus on means and methods of achieving usability. They do so by dictating what must be done to achieve a usable outcome, without necessarily indicating what that outcome might look like. As a result, the more prescriptive guidelines are, the fewer design alternatives there are and therefore fewer ways to achieve a usable outcome. In contrast, performance guidelines focus on the product or results of the design process. Performance guidelines typically suggest what the usable outcome should be without regard to how that outcome is achieved. As a result, performance-based guidelines allow greater flexibility in design outcomes by providing opportunities for designers to rely on their own interpretation and creativity to achieve a usable outcome. Among the four design strategies, only DfA included prescriptive guidelines.

Inclusion Criteria

The final version of UDMIG v.2.0 included all of the guidelines, either in whole or modified, from UU and MID. Three UD guidelines (UD 7a,b,d), which were related to the context of use, were taken out of the final set of UDMIG v2.0. This version also included 43 of the 52 (82.7%) guidelines from DfA. Five design guidelines were excluded because they applied to the environment, and four other guidelines were excluded because they applied specifically to desktop interfaces (see Table 2.5).

As an example, half of the Eight Golden Rules of Interface Design (i.e., enable frequent users to use shortcuts, offer informative feedback, design dialogs to yield closure, and support internal locus of control) were included in whole as they apply to mobile applications (Ruzic et al. 2016). In contrast, the other half of the guidelines (consistency, reversal of actions, error prevention and simple error handling, and reducing short-term memory load) were modified to fit the mobile touchscreen environment. In addition, four UD guidelines that cover low physical effort (Principle 6) and one guideline that considers size and space for approach and use (Principle 7) were slightly modified to fit the mobile touchscreen interfaces.

Table 2.5 Proportion of design guidance retained from each of the contributing sources

Design guidelines analyzed	Number of guidelines	Number (%) of guidelines included in UDMIG 2.0	Number (%) of guidelines modified in UDMIG 2.0
Universal design	30	27 (90%)	3 (10%) excluded
			5 (16.7%) modified
Design for aging	52	43 (82.7%)	9 (17.3%) excluded
Universal usability	8	8 (100%)	4 (50%) modified
Guidelines for handheld mobile device interface design	15	15 (100%)	0 (0%) modified

Final Guidelines

The final version of UDMIG v2.0 is organized into context and feature guidelines. Context guidelines relate to the design of the overall interface, which is the context of use. These guidelines are concerned with the design of the mobile touchscreen interface as a whole. For example, user interface needs to be designed to be usable by all people, regardless of their abilities and limitations. Feature guidelines cover the design of the specific features within the mobile interface that users interact with. For instance, user interface is designed to provide sufficient color contrast (e.g., color contrast for normal and large text should be more than 4.5:1). Additionally, guidelines provide the user with the option to change the color contrast (e.g., white on black vs. black on white). These are the characteristics of the interface features.

2.5 Feature Guidelines

1. **Choice in methods of use**. Provide different inputs and choices of input to accommodate variations in abilities, preferences, situations, and contexts of use. Viable alternatives for mobile devices are speech input, replacing the text or graphics, tactile input (Poupyrev et al. 2002), and hands-free and eye-free interaction (Gorlenko and Merrick 2003). Eye-free interaction provides the greatest freedom of movement as visual attention constrains body movement (Gorlenko and Merrick 2003). Allow for personalization to accommodate differences in usage patterns, preferences, abilities, and skill levels (Gong and Tarasewich 2004). In addition, users of mobile devices often need to focus on more than one task (Kristoffersen and Ljungberg 1999), and mobile application may not be the focal point of their current activities (Holland et al. 2001). Mobile devices that demand too much attention may distract users from more important tasks. Interfaces for mobile devices need to be designed to require as little attention as possible (Poupyrev et al. 2002).

2. **Range of literacy and language skills**. Allow for a range of literacy and language skills to accommodate all users. Regardless of user's language skills, knowledge, experience, and literacy level, the way in which design is used should be easy to understand (Sanford 2012). Choice of vocabulary and content of information is important due to various native languages (Fisk et al. 2009). Technical language used in instructions and help systems might be difficult for older adults as their educational attainment levels may be lower than that of younger adults. Reading level of text material needs to be kept at grade 10 or below (Fisk et al. 2009).
3. **Right-, left-, or no-handed use**. Provide right- or left-handed and single- or no-handed access and use to accommodate different abilities, preferences, and contexts of use, such as a significant number of additional people, objects, and activities in users' environments. Due to varying limitations while using mobile applications, such as a significant number of additional people, objects, and activities in users' environments, they could have the ability to use one hand or no hands at all. Therefore, allowing operations with 0, 1, or 2 hands becomes extremely important to the viability of the interface.
4. **Adaptation to users' pace**. Provide adaptable pace to accommodate novice and expert users, different ages, abilities, preferences, situations, and contexts of use. Time constraints need to be taken into account in initial application availability and recovery speed for mobile platforms (Gong and Tarasewich 2004). When time is critical, waiting a few minutes for an application to start may not be in the user's best interest. Users may need to quickly change or access functions or applications in different contexts of use (Poupyrev et al. 2002). In these situations, work performed would have to be saved and resumed later without any loss (Poupyrev et al. 2002). Add personalization to accommodate differences among users (Gong & Tarasewich 2004). Ensure speech rates of 140 wpm or less (Fisk et al. 2012). Avoid compressing and speeding the speech rates because of older adults' slower rate of processing. Have appropriate temporal constraints for carrying out commands (e.g., drop-down and pop-up menu durations should be long enough to carry out the commands). Screen characters and targets should be conspicuous and accessible (e.g., auditory information should be presented at the proper pitch, frequency, and rate). Make system adaptable and flexible to different user levels in a way that it grows with the user's experience and skills (Fisk et al. 2012).
5. **Minimization of hazards and unintended actions**. Discourage unconscious action in all tasks to prevent adverse outcomes. Design should minimize hazards and unintended actions that could have unwanted outcomes (e.g., "are you sure?" prompts) (Fisk et al. 2012; Sanford 2012). Give preference to text warnings as opposed to symbols and icons that take longer to learn and are less likely to be remembered. Avoid short-duration menu displays because of the slower processing speed of older adults (Fisk et al. 2009). Frequent and important actions should be visible and easily accessible (Fisk et al. 2012). Very simple operations (e.g., power on/off) should not trigger anything potentially harmful (Gong and Tarasewich 2004). Rapid pace in addition to the small

physical design of the mobile environment creates a serious need for error prevention and minimization of unwanted actions. For example, the proximity of buttons on these small devices creates a potential problem.

6. **Informative feedback**. Provide informative feedback for actions and task completion to confirm proper use. For every operator action, there should be some system feedback (Shneiderman 1986), such as a beep when pressing a key or an error message for an invalid input value. For frequent and minor actions, the response can be modest, while, for infrequent and major actions, the response should be more substantial (Gong and Tarasewich 2004). It needs to be understandable to the user (Gong and Tarasewich 2004). Have feedback about task completion, confirmation of activity, and the current state (Fisk et al. 2012). Minimize clutter: visual (many display items in one location), auditory (many sounds), cognitive (many things to keep in memory), and movement related (many small response items).
7. **Different modes of use**. Provide different modes (pictorial, verbal, tactile) for redundant presentation of essential information to accommodate different abilities, preferences, and contexts of use (Sanford 2012). For a design to effectively communicate necessary information to users with various abilities and preferences regardless of ambient conditions, it should provide as many modes as possible. It is beneficial to use alternative interaction modes such as sound (Poupyrev et al. 2002). Use frequencies less than 4000 Hz for audio output (Fisk et al. 2012). In addition to sound (Poupyrev et al. 2002), use vibration and light as sensory channels (Fisk et al. 2012). Use low-frequency (25 Hz) vibration due to unimpaired sensitivity to this level of frequency with age, and avoid high-frequency vibration (60 Hz and above) (Fisk et al. 2009). Provide parallel visual and auditory language presentation (e.g., speech recognition and closed caption text for public addresses). Use speech recognition control and input when users are very restricted in manual dexterity and the ambient noise level is low in the environment. Provide both tactile/haptic and auditory feedback with keypads. In noisy environments and glare situations, when auditory and visual output would be difficult to process or would be disruptive to users' performance, prefer tactile output device for simple signaling (e.g., moderate frequency vibration of around 25 Hz) (Fisk et al. 2012).
8. **Simple error handling**. As far as possible, design the system so the user cannot make a serious error (Shneiderman 1986). Provide warnings of hazards and errors to ensure safety and prevent inadvertent mistakes/outcomes (Sanford 2012). Arrange elements to minimize errors and hazards. For example, have most frequently used elements as most accessible, and have hazardous elements hidden or removed. If an error is made, the system should be able to detect the error and offer simple, comprehensible mechanisms for handling the error (Shneiderman 1986). The need for error prevention becomes more critical due to the more rapid pace of events in the mobile environment (Gong and

Tarasewich 2004). Error prevention also needs to take the physical design of mobile devices into account. Smaller device sizes make the proximity of buttons to one another more of a potential problem. Warning signals should have frequency ranges from 500 to 200 Hz and intensity of at least 60 dB at the ear of the listener (Fisk et al. 2012). Repetitively flash the information for important visual warning messages. For important auditory warning messages, select output systems (e.g., speakers), which emit sounds in the range of 500–1000 Hz, and repeat the message until acknowledged. Minimize the use of attention-catching techniques, such as flashing and scrolling text and images in the periphery (e.g., advertisements on web pages), because older adults are less able to ignore distractions (Fisk et al. 2009). In addition, they have less effective useful fields of view, which make them less likely to process events in the periphery in a successful manner similar to that of young adults. This is especially applicable to the pages with important information, such as warnings and errors.

9. **Easy reversal of actions**. Provide fail-safe features to minimize hazards and errors. Since the user knows that errors can be undone, their anxiety is relieved, and they are encouraged to explore unfamiliar options (Shneiderman 1986). The units of reversibility may be a single action, a data entry, or a complete group of actions. Allowing easy reversal of actions may be more difficult for mobile devices because of a lack of available resources and computing power (Satyanarayanan 1996). The greater susceptibility of wireless communications to connectivity losses makes tracking of past states more difficult (Satyanarayanan 1996, Kristoffersen and Ljungberg 1999). Mobile devices should rely on network connectivity as little as possible (Gong and Tarasewich 2004).
10. **Multiple and dynamic contexts.** Provide multiple and dynamic contexts to accommodate variations in the environment. Mobile platform users can have a significant number of additional people, objects, and activities vying for their attention outside the application itself (Tarasewich 2003). In addition, environmental conditions (e.g., brightness, noise levels, weather) can change depending on location, time of day, and season. The usability or appropriateness of an application can change based on these different context factors (Kim et al. 2002). For example, in the presence of strangers, users may feel uncomfortable speaking input aloud, and certain places (e.g., libraries) might restrict the use of voice input. Small text sizes may work well under office conditions but suddenly become unreadable in bright sunshine or in dimly lit spaces. Thus, allow users to configure output to their needs and preferences (e.g., text size, brightness) (Gong & Tarasewich 2004). Have the application adapt itself automatically to the user's current environment. Implement context-awareness, self-adapting functionalities, and universal control features, which would work regardless of the context and environment.

2.6 Context Guidelines

1. **Same means of use.** Provide the same means of use for people with diverse ranges of abilities, identical whenever possible, and equivalent when not. Ensure provisions for privacy, security, and safety that are equally available to all to avoid segregating or stigmatizing anyone. Participation in all activities, experiences, and application uses should be provided to everyone to eliminate the need for specialized design and signage (Sanford 2012). Design useful and accessible interfaces for people with diverse ranges of abilities.
2. **Design appealing to all.** The design is appealing to all to enhance usability and marketability. Part of designing an enjoyable user experience is aesthetics (Gong and Tarasewich 2004). "Aesthetics in use" was defined as dynamic interaction that invokes a positive effective response from the user (Karlsson and Djabri 2001). In addition, color and its manipulation are important considerations for visual interfaces. Shneiderman (1992) offered color use guidelines for interfaces that can be carried over to mobile devices, although some of the effects of color may be different on smaller screens. Moreover, besides usability and aesthetics, emotion involves a large part of our interaction with objects (Norman 2004).
3. **Simple and natural use.** Eliminate complexity, and arrange information consistent with its importance to allow for natural use (Sanford 2012). For example, next and back buttons should be larger, in colors that stand out, and arranged in linear order. Mobile devices are limited with the amount of information that they can present at one time on their small screens (Gong and Tarasewich 2004). Reading large amounts of information from such devices can require large amounts of scrolling and focused concentration. To reduce distraction, interactions, and potential information overload, a better way of presenting information might be through multilevel or hierarchical mechanisms (Brewster 2002). For example, users may not need or want the entire content of a message, but they may wish to receive a notification that a message is available, along with an indication of its importance. That way, they can make decisions whether or not to stop the primary task in order to access the contents of the message. Frequent and important actions should be visible and easily accessible (Fisk et al. 2012). Organize information within natural or consistent groupings (e.g., group-related information and have most frequent operations highest on the menu structure) (Fisk et al. 2012). Menu structure should match the medium of presentation that the task demands, as well as the users' capabilities. Avoid scrolling text because it is difficult to process, especially horizontal formats (Fisk et al. 2012). Use a slow scrolling rate if it is necessary to use. Minimize clutter: visual (many display items in one location), auditory (many sounds), cognitive (many things to keep in memory), and movement related (many small response items).
4. **Consistency with expectations.** Provide consistency with expectations and intuition to allow natural, intuitive use. Consistent sequences of actions should be required in similar situations; identical terminology should be used in prompts, menus, and help screens, and consistent commands should be employed

throughout. The system functions should match users' expectations (e.g., mental models based on previous experiences should match how the interface system works) (Fisk et al. 2009). As a secondary option, provide training which enables users to create the appropriate mental models. Always, where possible, promote proper design over the provision of training. Provide consistency across multiple platforms and devices for the same application when users switch between their desktop and mobile devices (Chan et al. 2002), including the "look and feel," names, color schemes, dialog appearances (Gong and Tarasewich 2004), and standard layouts (Fisk et al. 2009). Create device-independent I/O methodologies, and avoid using methods specific to mobile platforms (Isokoski and Raisamo 2000). Ensure standardized format, and keep consistent location of target items within and if possible between the applications (e.g., help information and error messages should always appear at the same location) (Fisk et al. 2012).

5. **Accuracy and precision.** Facilitate the accuracy and precision required to accommodate different abilities, preferences, situations, contexts of use, ages, and novice and expert users, and enhance users' experience. As the frequency of use increases, so do the user's desires to reduce the number of interactions and to increase the pace of interaction (Shneiderman 1986). Abbreviations, function keys, hidden commands, and macro facilities are very helpful to an expert user. The limitation of human information processing in short-term memory requires that displays be kept simple, multiple-page displays be consolidated, screen-motion frequency be reduced, and sufficient training time be allotted for codes, mnemonics, and sequences of actions (Shneiderman 1986). Users should rely on recognition of function choices instead of memorization of commands (Gong and Tarasewich 2004). Very little memorization should be required during the performance of tasks (Chan et al. 2002). Use modalities such as sound to convey information where appropriate. When in the mobile environment, a user has to potentially deal with more distractions than with a desktop computer (Tarasewich 2003). A mobile application may not be the focal point of the user's current activities (Holland et al. 2001), and a user may not be able to suspend his or her primary task to interact with the mobile device (Gorlenko and Merrick 2003, Kristoffersen and Ljungberg 1999). Using alternative interaction modes such as sound can be beneficial (Poupyrev et al. 2002). In addition, provide personalization to allow for variations among users (Gong and Tarasewich 2004). Allow users to adjust sound volumes, and provide instructions regarding how to perform these adjustments.

   Provide at least 50:1 contrast (e.g., black text on white background) (Fisk et al. 2012). Make sure that color discriminations can be made easily by signaling important information using short wavelength (blue-violet-green) contrasts, using black-on-white or white-on-black text, and avoiding colored and watermarked backgrounds for display of text (Fisk et al. 2012). 3D and VR displays may induce spatial confusion in older adults, which may require greater investment in working memory to resolve. However, with guided training and practice, older adults may benefit from 3D interactive environments (Czaja and Sharit 2012). Avoid style sheets that prevent users from increasing the font size

with the browser software (Fisk et al. 2012). Provide instruction to user about how to change screen resolution. Minimize clutter: visual, auditory, cognitive, and movement related. Provide appropriate temporal constraints for carrying out commands (e.g., drop-down and pop-up menu durations should be long enough to carry out the commands). Screen characters and targets should be conspicuous and accessible (e.g., font size should be 12 point and higher).

6. **Internal locus of control.** Let users feel they are in control (output), so provide a choice of alternative solutions for control over decision-making. Users want to be in charge of the system and have the system respond to their actions, rather than feel that the system is controlling them (Shneiderman 1986). The system should be designed such that users initiate actions rather than respond to them. It should let the user navigate it on their own. The system should not be deterministic; it should provide a choice. For example, to enhance user control, provide a choice of linear vs. random access.
7. **Maximized "legibility" of essential information.** Provide contrast between essential information and its surroundings, differentiate elements in ways that can be described, and allow for compatibility with assistive techniques/devices to increase "legibility" of essential information (Sanford 2012). Screen characters and targets should be conspicuous and accessible (e.g., icons should be large enough to select easily) (Fisk et al. 2012). Use at least 12-point serif or sans serif fonts (e.g., Arial, Helvetica, Times Roman), preferably 14-point and bigger (Kascak et al. 2013a, b). Avoid cursive and decorative fonts, and use of all uppercase letters since it slows down reading. In mixed-case situations, uppercase text attracts more attention than lowercase ones. Provide at least 50:1 contrast (e.g., black text on white background) (Fisk et al. 2012). Make sure that color discriminations can be made easily by signaling important information using short wavelength (blue-violet-green) contrasts, using black-on-white or white-on-black text, and avoiding colored and watermarked backgrounds for display of text (Fisk et al. 2012). Provide a site map. Menu structure should match the medium of presentation, the task demands, and the users' capabilities. Frequent and important actions should be visible and easily accessible (Fisk et al. 2012). Provide good structure (e.g., grammar) in spoken and written text (Fisk et al. 2009). Pause after phrases and ends of sentences when speaking. Prefer videoconferencing to talking on a phone because of using visual cues as a contextual support. Ensure adequate pauses in speech at grammatical boundaries (e.g., after phrases and at the end of the sentence). Match voice characteristics to situation (Fisk et al. 2012). For announcements use male voices rather than female ones. To get attention select female over male voices. Avoid synthesized speech.
8. **Clear and understandable navigation structure.** Provide clear and understandable navigation structure to allow seamless and intuitive use. Allow users to navigate seamlessly (e.g., next, back buttons). Provide navigation assistance (e.g., help, review buttons) for how to navigate to specific points in the system (Fisk et al. 2009). This includes navigation to not only the home page but any relevant page. Attentional cues (e.g., highlighting) should be used to support

the information search. Make system status clear to users (such as history mode vs. review mode vs. transfer mode). Provide search history to allow users to know which pages they have visited (Fisk et al. 2012).

9. **Dialogs that yield closure.** Design dialogs to yield closure to allow the satisfaction of accomplishment and completion. Sequences of actions should be organized into groups with a beginning, middle, and end (Shneiderman 1986). Organize information within natural or consistent groupings (e.g., group-related information and have most frequent operations highest on the menu structure) (Fisk et al. 2012). Users should be given the satisfaction of accomplishment and completion, a sense of relief, and an indicator to prepare for the next group of actions, no matter where they are (Shneiderman 1986). Indicate clearly where the user currently is at any point of time (Fisk et al. 2012). The sequences of actions should be available and visible in the interface, and the user should not be expected to remember them (Fisk et al. 2009). Provide search history to allow users to know which pages they have visited (e.g., change the color of pages previously visited on a list of pages). Clearly communicate current system status. It needs to be clear which option is active and what the consequences of an action are.
10. **Low physical effort.** Use reasonable operating forces; minimize repetitive actions and sustained physical effort to provide ease of use, efficiency, and comfort, and minimize fatigue (Sanford 2012). Avoid double-clicking (Fisk et al. 2012). Scrolling text should be avoided. If necessary to use, use slow scrolling rate. Minimize steps (basic tasks, such as pressing a key) (Fisk et al. 2009).
11. **Variations in hand and grip size.** Accommodate variations in hand and grip size to allow ease of use (Sanford 2012). Use large keys with clear markings and appropriate inter-key spacing on a keypad (Fisk et al. 2012).
12. **Natural body position.** Maintain natural body position to provide comfort and minimize fatigue. Design should be able to be used from a natural body position to provide physical ease of use and low physical effort (Sanford 2012).

2.7 Discussion

As people age, they experience declines in both health and function. This not only suggests that mobile eHealth applications are a potential means to meet seniors' health-related needs but also that their usefulness is dependent upon the usability of the application interfaces to fit users' abilities. Whereas UD, DfA, UU, and MID are design strategies that are used to guide the design of mobile interfaces, none are sufficiently comprehensive to ensure that mobile eHealth user interfaces will be usable by older adults. UU, DfA, and UD guidelines were not originally developed for mobile interfaces, although UD has recently included this platform to a certain extent. MID fails to acknowledge diversity and the ranges of limitations that the aging population faces. Adaptation and addition of some of the guidelines were

necessary to accommodate design for the interactive mobile interfaces for older adults.

UDMIG v.2.0 are an inclusive and comprehensive set of guidelines developed to guide design processes of mobile eHealth interfaces for the aging population. They are divided into three sets of guidelines: context, features, and environment. Context guidelines relate to the design of the overall interface, feature guidelines guide the characteristics of the features of the user interface, and environment guidelines help with the design of the space and context of use. Person component is present in all the guidelines, which all describe how to accommodate people with different abilities.

The guidelines were based on the four established design strategies for desktop and mobile user interfaces for general and aging population and published research on interactive mobile eHealth interfaces and designing for the aging population. The significance of the UDMIG v.2.0 is in its completeness and integration of the four common strategies for designing interactive mobile interfaces for older adults. This unique set of the guidelines is useful to human-computer interaction (HCI) researchers working in a field of usability and mobile eHealth user interface design, as well as to industry leaders who develop mobile eHealth devices and applications for our aging population.

UDMIG v.2.0 are developed to help with the mobile eHealth interface design for the aging population. In addition to the interface itself, the context of use and its environment are important as well. A number of guidelines, originally called environment, addressed the appropriate lighting and glare, adjustable positioning, minimized background noise and reverberation, and space for use of assistive devices. Environment guidelines describe guidelines that direct the design of space in which the mobile interface is used. For example, eyes of older adults admit about one third of the light to the retina under low-light conditions than the eyes of the young adults. Therefore, the environment guideline 1: Appropriate lighting and glare requires adequate lighting, minimized glare (Fisk et al. 2012), a clear line of sight to important elements (Sanford 2012), and adjustable display when feasible (Fisk et al. 2012).

Environment guideline 2: Adjustable positioning requires adjustable height, depth, width, and angle from a standing or seated position for a comfortable reach to all components. Appropriate size and space should be provided for approach, reach, manipulation, and use regardless of the user's body size, posture, and mobility (Sanford 2012) and adjustable display when possible (Fisk et al. 2012). Guideline 3 states that minimized background noise and reverberation should be provided for understanding audio output (e.g., use sound-absorbing materials on walls, ceilings, and floors; provide wireless headphones in public settings; avoid background music during spoken language) (Fisk et al. 2012). Environment guideline 4: Space for the use of assistive devices requires adequate space to accommodate independent and assisted use (Sanford 2012). When multiple devices are required, consider the issue of "homing," moving the hands to the home row key position, following use of the pointing device (Fisk et al. 2012).

2.8 Conclusion

UDMIG v.2.0 were developed to ensure the usability of future mobile eHealth technologies by older adults through a universal design strategy that accommodates all users to the greatest extent possible. Nonetheless, while the guidelines are intended to promote universal usability, they require validation through application and evaluation with users who represent a range of abilities.

Future planned work includes the development and testing of an eHealth application for people aging with multiple sclerosis (MS). MS is a complex inflammatory disorder of the central nervous system (CNS). Individuals with MS are an ideal end-user population for an eHealth application that would be developed based on the UDMIG. They represent a diverse user group that has symptoms that vary widely from an individual to an individual, but also within individuals over time. Moreover, MS presents with symptoms that share many of the functional limitations associated with aging, including decline in muscle strength, problems with balance, weakness, fatigue, reduced sensation, vision impairments, bowel and bladder dysfunction, cognitive impairment, pain, osteoporosis, and sleep disturbances (Stern et al. 2010; Stern 2005; Finlayson 2002; Fleming and Pollak 2005). To accommodate this group of users, UDMIG v.2.0 will be used to design a mobile eHealth application based on their health self-management needs. The application will be then evaluated for its usability and utility by people who have been diagnosed with MS for at least 5 years. Results of the study will be used to further refine both the eHealth application and the UDMIG.

References

Becker SA (2004) A study of web usability for older adults seeking online health resources. ACM Trans Comput-Hum Interact (TOCHI) 11:387–406

Bederson BB, Lee B, Sherman RM, Herrnson PS, Niemi RG (2003) Electronic voting system usability issues. Proceedings of the SIGCHI conference on Human factors in computing systems. ACM, 145–152

Brewster S (2002) Overcoming the lack of screen space on mobile computers. Pers Ubiquit Comput 6:188–205

Chadwick-Dias A, Mcnulty M, Tullis T (2003) Web usability and age: how design changes can improve performance. ACM SIGCAPH Computers and the Physically Handicapped. ACM, pp 30–37

Chan SS, Fang X, Brzezinski JR, Zhou Y, Xu S, Lam J (2002) Usability for mobile commerce across multiple form factors. J Electron Commerce Res 3:187–199

Connell BR, Jones M, Mace R, Mueller J, Mullick A, Ostroff E, Sanford J, Steinfeld E, Story M, Vanderheiden G (1997) Universal design principles [online]. Center for Universal Design, College of Design, North Carolina State University Available: https://www.ncsu.edu/ncsu/design/cud/about_ud/udprinciplestext.htm. Accessed 12 June 2016

Czaja SJ, Sharit J (2012) Designing training and instructional programs for older adults. CRC Press, London

Falls Among Older Adults (2013) An overview [Online]. Centers for disease control and prevention. Available: http://www.cdc.gov/homeandrecreationalsafety/falls/adultfalls.html. Accessed 21 Apr 2014
Finlayson M (2002) Health and social profile of older adults with MS: findings from three studies. Int J MS Care 4:139–151
Fisk AD, Rogers WA, Charness N, Czaja SJ, Sharit J (2009) Designing for older adults: principles and creative human factors approaches. CRC press, Boca Raton
Fisk AD, Rogers WA, Charness N, Czaja SJ, Sharit J (2012) Designing for older adults: principles and creative human factors approaches. CRC press
Fleming WE, Pollak CP (2005) Sleep disorders in multiple sclerosis. Semin Neurol:64–68
Gong J, Tarasewich P (2004) Guidelines for handheld mobile device interface design. Proceedings of DSI 2004 Annual meeting. Citeseer, 3751–3756
Gorlenko L, Merrick R (2003) No wires attached: usability challenges in the connected mobile world. IBM Syst J 42:639–651
Holland S, Morse DR, Gedenryd H (2001) Audio GPS: spatial audio in a minimal attention interface. Environment 1:3
Isokoski P, Raisamo R (2000) Device independent text input: a rationale and an example. Proceedings of the working conference on Advanced visual interfaces. ACM, pp 76–83
Iwarsson S, Ståhl A (2003) Accessibility, usability and universal design-positioning and definition of concepts describing person-environment relationships. Disabil Rehabil 25:57–66
Karlsson P, Djabri F (2001) Analogue styled user interfaces: an exemplified set of principles intended to improve aesthetic qualities in use. Proceedings of Mobile HCI 2001: Third international workshop on human-computer interaction with mobile devices. Citeseer
Kascak L, Rebola CB, Braunstein R, Sanford JA (2013a) Icon design to improve communication of health information to older adults. Commun Des Q Rev 2:6–32
Kascak L, Rébola CB, Braunstein R, Sanford JA (2013b) Icon design for user interface of remote patient monitoring mobile devices. Proceedings of the 31st ACM international conference on Design of communication. ACM, pp 77–84
Kascak L, Rébola CB, Sanford J (2014) Integrating Universal Design (UD) principles and mobile design guidelines to improve design of mobile health applications for older adults. Healthcare Informatics (ICHI), IEEE international conference on, 2014. IEEE
Kascak LR, Liu EY, Sanford JA (2015) Universal design (UD) guidelines for interactive mobile voting interfaces for older adults. Universal Access in Human-Computer Interaction. Access to the Human Environment and Culture. Springer
Kim H, Kim J, Lee Y, Chae M, Choi Y (2002) An empirical study of the use contexts and usability problems in mobile internet. System Sciences, 2002. HICSS. Proceedings of the 35th annual Hawaii international conference on, 2002. IEEE, pp 1767–1776
Kristoffersen S, Ljungberg F (1999) "Making place" to make IT work: empirical explorations of HCI for mobile CSCW. Proceedings of the international ACM SIGGROUP conference on Supporting group work. ACM, pp 276–285
Law CM, Yi JS, Choi YS, Jacko JA (2008) A systematic examination of universal design resources: part 1, heuristic evaluation. Univ Access Inf Soc 7:31–54
Lawton MP, Nahemow L (1973) Ecology and the aging process
Mace R (1988) Universal design: housing for the lifespan of all people. US Department of Housing and Urban Affairs, Washington, DC
Meiselwitz G, Wentz B, Lazar J (2010) Universal usability: past, present, and future. Now Publishers Inc., Hanover
Morrell RW (2001) Older adults, health information, and the world wide web. Psychology Press
Nichols TA, Rogers WA, Fisk AD (2006) In: Salvendy G (ed) Design for aging, in handbook of human factors and ergonomics, 3rd edn. Wiley, Hoboken. https://doi.org/10.1002/0470048204.ch54
Norman DA (2004) Emotional design: why we love (or hate) everyday things. Basic books

Poupyrev I, Maruyama S, Rekimoto J (2002) Ambient touch: designing tactile interfaces for handheld devices. Proceedings of the 15th annual ACM symposium on user interface software and technology. ACM, pp 51–60

Ruptash S (2013) Universal design through passion, knowledge and regulations? Trends in Universal Design**,** 24

Ruzic L, Lee ST, Liu EY, Sanford JA (2016) Development of universal design mobile interface guidelines (UDMIG) for aging population. Universal access in human-computer interaction. Access to the human environment and culture. Springer

Sanford JA (2012) Universal design as a rehabilitation strategy: design for the ages. Springer, New York

Satyanarayanan M (1996) Fundamental challenges in mobile computing. Proceedings of the fifteenth annual ACM symposium on Principles of distributed computing. ACM, pp 1–7

Shneiderman B (1986) Eight golden rules of interface design. Disponible en

Shneiderman B (1992) Designing the user interface: strategies for effective human-computer interaction. Addison-Wesley, Reading

Shneiderman B (2000) Universal usability. Commun ACM 43:84–91

Shneiderman B (2003) Promoting universal usability with multi-layer interface design. ACM SIGCAPH Computers and the Physically Handicapped. ACM, pp 1–8

Shneiderman B, Plaisant C (1987) Designing the user interface: strategies for effective human-computer interaction. Addison-Wesley Longman Publishing Co., Inc, Boston, p 672

Stern M (2005) Aging with multiple sclerosis. Phys Med Rehabil Clin N Am 16:219–234

Stern M, Sorkin L, Milton K, Sperber K (2010) Aging with multiple sclerosis. Phys Med Rehabil Clin N Am 21:403–417

Tarasewich P (2003) Designing mobile commerce applications. Commun ACM 46:57–60

Universal Design Policy (2001) Winnipeg, Canada: City of Winnipeg, Mayors access advisory committee

Zajicek M (2001) Interface design for older adults. Proceedings of the EC/NSF workshop on Universal accessibility of ubiquitous computing: providing for the elderly. ACM, pp 60–65

Ljilja Ruzic is a Ph.D. Candidate at the College of Design, Georgia Institute of Technology, with a concentration in human-centered computing and a special interest in user experience research and design, human-computer interaction, accessibility, universal design, design for aging, mobile health technologies, and industrial design.

At the Center for Assistive Technology and Environmental Access (CATEA), Ljilja works as a Graduate Research Assistant on universal design of mobile health technologies for people aging with multiple sclerosis. Furthermore, her research includes the work on the universally designed voting interface for older adults and people with vision, cognition, and dexterity limitations.

Among her awards, Ljilja has won the SIGDOC 2013 Graduate Student Competition Paper Award, 1st Place at the Convergence Innovation Competition at GaTech 2012, TechSAge Mobile App Development Funding, and Auxiliary Services IMPACT Scholarship.

Jon A. Sanford is a Professor in the School of Industrial Design and Director of the Center for Assistive Technology and Environmental Access at Georgia Tech. He is internationally-recognized for his expertise in universal design, accessible design and design for aging and is the Director of the Rehabiliation Engineering Research Center on Technologies for Successful Aging with Disability, supported by the Department of Health and Human Services. He has over 300 scholarly presentations and publications and is the author of: “Design for the Ages: Universal Design as a Rehabilitation Strategy”.

Chapter 3
mHealth and the Digital Cyborg Body: The Running Apps in a Society of Control

Igor Sacramento and Vanissa Wanick

Abstract Mobile apps and new technologies are changing the way people deal with their personal health. There is a new and symbiotic relationship between technologies and individuals, which results in a constant sense of monitoring, improving self-knowledge and transforming bodies into digital cyborgs. The current chapter aims to analyse the propagation of running apps as a reflection of a permanent monitoring of bodies in the contemporary society. With this in mind, we provide a critical review of issues related to the Quantified Self (QS) movement, combined with principles borrowed from gamification, control and mHealth technologies. In this chapter, we show a transformation of the body into data, particularly through design strategies, such as data visualisation, graphic feedback and social media integration. The main contribution of this chapter relies on the discussion about datification, which could help to provide a guideline for the understanding of the perspectives of the self in a society of control.

Mobile apps and new technologies are changing the way people deal with their personal health. There is a new and symbiotic relationship between technologies and individuals, which results in a constant sense of monitoring, improving self-knowledge and transforming bodies into digital cyborgs. The current chapter aims to analyse the propagation of running apps as a reflection of a permanent monitoring of bodies in the contemporary society. With this in mind, we provide a critical review of issues related to the Quantified Self (QS) movement, combined with principles borrowed from gamification, control and mHealth technologies. In this

I. Sacramento (✉)
Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

Oswaldo Cruz Foundation, Rio de Janeiro, Brazil
e-mail: igor.sacramento@icict.fiocruz.br

V. Wanick
University of Southampton, Southampton, UK

Winchester School of Art, Winchester, UK
e-mail: v.w.vieira@soton.ac.uk

H.R. Marston et al. (eds.), *Mobile e-Health*, Human–Computer Interaction Series,
DOI 10.1007/978-3-319-60672-9_3

chapter, we show a transformation of the body into data, particularly through design strategies, such as data visualisation, graphic feedback and social media integration. The main contribution of this chapter relies on the discussion about datification, which could help to provide a guideline for the understanding of the perspectives of the self in a society of control.

3.1 Introduction

Currently, there are mHealth devices like wearable fitness gadgets, smart wristbands, intelligent glucose metres and mobile apps that not only monitor but also quantify all types of activities, from financial expenses to professional and personal productivity goals, mood swings, calorie expenditure, physical activity, level of hydration, menstruation, stress levels, sleep quality and others. This reflects a constant incorporation of technology into people's daily lives, transforming the relationship between doctor and patient, for example. When users interact with such devices and log their food intake, pain or glucose levels, they provide data that can be useful for doctors to gain a holistic view of patient's performance (Bentley and Tollmar 2013).

This new apparatus of online digital technologies that deliver healthcare, preventive medicine and health promotion has facilitated the measurement and monitoring of functions and activities centred on people's bodies, encouraging self-care actions among patients with chronic diseases. For instance, a study of people aged 65 and over with mild cognitive impairment and mild Alzheimer's dementia showed that wearable media can help them to remember events (Maier et al. 2015). These technologies can also provide a new approach to identifying and preventing illnesses and diseases. While the digital health approach to the body and health spans the arc from patient care to public health surveillance techniques, the discussion is largely directed at the implications for mobile health in relation to the practice of health promotion or what Lupton (2016a, p.2) refers to as "digitised health promotion". It seems that prevention of diseases and the promotion of health are more personalised. The numerous healthcare apps offer people an opportunity to engage in self-monitoring of their health-related behaviours. However, this is used to track individuals and to collect mass data on these behaviours for use in monitoring populations. The personalised aspect of this approach focuses, in fact, on collecting as much data as possible about individuals and their health states, everyday habits and the social and geographical environment in which they live: their personal health informatics is a way of monitoring people's habits and practices. Nevertheless, personalisation is also a way to individualise responsibility for health, linking the idea of "good health" to the use of mobile and self-tracking technologies.

The concept of mHealth represents applications, sensors and networks that combine mobile computing and health behaviours (Istepanian and Woodward 2016). In this scenario, smartphones gained importance for enabling the production and consumption of information in real time. For instance, several applications have been

created, for example, *Fitbit*, *Nike+* and *Runkeeper*, which are particularly focused on running performance. Another example is the application *MyFitnessPal*, which provides a tailored training program based on user physical data. This shows that adopting a healthy behaviour could be increasingly convenient. However, mHealth applications are not restricted to smartphones. With advances in technologies such as bio-wearables (e.g. technology that merges with the body, like electronic tattoos) and the Internet of things (e.g. sensors coupled with objects), mHealth applications are starting to merge with individuals' bodies. For example, it is possible to monitor an individual's heartbeat, location, blood pressure and temperature through an intelligent vest composed of several sensors that collect physiological data (Pandian et al. 2008).

This constant monitoring enabled by mHealth applications is also enhanced by the use of social media. People are able to monitor and share their performances online with anyone, as mHealth applications offer features for data publication on social networking sites. For example, *Nike+* connects runners to *Facebook*, and every time someone "likes" their performance, it is possible to hear applause of encouragement. In fact, this strategy tends to be successful, as people tend to change their behaviours just to receive a "like" from a friend (Hamari and Koivisto 2015). However, social networking sites are not free from any form of surveillance and monitoring (Finnemann 2014). What happens is just the opposite. The surveillance and monitoring systems are immanent to such networks, being an integral part of both system efficiency and data analysis. This data is provided by users in order to optimise social relations and social networking services. Thus, social networks rely on mutual consent and supervision, which contributes to a certain voyeurism and exhibitionism. Although this social feature could function as an encouragement for people to maintain their behaviour, it might not work for everyone. For example, users might feel embarrassed while sharing specific aspects about their health on a social network (Dennison et al. 2013).

Another characteristic of mHealth apps is that the majority utilise gamification as a strategy to engage and motivate users to maintain and improve their health performance (Hamari and Koivisto 2013; Miller et al. 2014). The idea behind gamification is the utilisation of game design strategies in order to transform non-leisure situations into gameful environments (Deterding et al. 2011). As games are engaging tools, gamification could unlock the power of changing people's behaviour (Almarshedi et al. 2016), particularly through feedback loops and positive reinforcement (Schrape 2014). In the context of health applications, leaderboards, levels and digital rewards (e.g. badges and points, real-world prizes, competitions and social/peer pressure) are the usual gamified strategies (Lister et al. 2014). For example, Dithmer et al. (2015) have created a platform to assist heart patients through leaderboards, achievements and relationships, involving both patients and relatives in a collaborative way. Another example is the application *SuperBetter*, which motivates users to become more resilient and overcome personal difficulties through quests and challenges, which could be personalised through choices in the application. This means that gamification functions as an enabler of desired behaviours and self-monitoring through user participation and rewards.

This relationship between gamification and self-monitoring could develop a high level of surveillance, as users' behaviours are being monitored and stored in the form of user data (Whitson 2014). In this context, the contemporary bodies could be considered and treated as systems of data and bundles of information. Combined with the power of mHealth technologies, the transformation of bodies into data becomes blurred, particularly when considering issues like security, data privacy and data ownership. For example, user data gathered from mHealth devices can be used by third parties to sell health insurance deals to prospective clients (Lupton 2016a, b).

This transformation of bodies into data through self-monitoring is the core discussion of the concept of Quantified Self (QS). The Quantified Self (QS) promotes self-monitoring of daily habits, through the discovery of trends and correlations on people's behaviour and health, enhancing the knowledge that people have upon their own bodies. This form of self-knowledge is impregnated with the discourses of biomedicine, in which individuality is translated into numbers, echoing the idea that what can be measured can be improved (Lupton 2013).

In the last decade, the emergence of a new generation of wearable devices and mobile applications has allowed the appearance of a new form of self-objectification, which is known as self-monitoring (Lupton 2013). Small, discreet observation machines with persistent, uninterrupted attention, carried close to the body, began to be used by individuals to quantify behavioural and biometric indicators such as weight, number of steps taken on a given day, mood swings, stress levels, happiness, sleep quality, expenditure and calorie intake and physical and mental performance. From the exchange of experiences on the use of these devices and on the data produced by them, the group that constitutes the object of study of the Quantified Self (QS) emerged. This movement originated in 2008 in the Bay Area of San Francisco (USA), whose motto is the search for self-knowledge through numbers; particularly any intervention or experimentation that can make people healthier, happier and productive appears within the broad scope of this movement (Lupton 2013).

Self-monitoring has a strong relationship with self-knowledge. After all, for the quantified selves, the data, their collection and analysis are not simply instruments to produce and communicate knowledge about the body, health and disease – the data are, above all, subjective tools. In a world where the collection, treatment and production of knowledge from the analysis of large masses of data is a reality for governments and corporations, the quantified selves propose their appropriation in the personal sphere and affirm that they are instruments to unveil the self, to discover and to produce. In a consonant approach, the emerging self-monitoring device and application market demands data as the basis of subjective and identity processes. Its products are not only advertised as instruments to produce information about bodies, their biology, their habits and functional mechanisms, but as tools that subsidise the production of knowledge about the subjects from these indicators, in a reflexive attitude. This formula, moreover, was well summarised by the application *The Eatery*[1]; the system consists of a photographic diary that promises to help

[1] Available at https://itunes.apple.com/gb/app/the-eatery/id468299990.

individuals to eat better, refusing to approach calorie counting with the slogan "other apps tell you about food. We tell you about yourself".

As Smith and Vonthethoff (2016) note, discourses of personal responsibility were prevalent motives and outcomes in many of the QS presentations. There is a mutually related discourse of self-imperfection and self-improvement in the QS community, specifically prevalent in the narratives expressed by those seeking to enhance their health states through the objectification of data. So, as Smith and Vonthethoff (2016, p.13) explain, "data are fetishized to the point where they come – literally and metaphorically – to speak on behalf of the embodied referents they represent, and to provide the divine instruction, discipline, and impetus needed to enact a lifestyle intervention. They are in this sense a medium of subjectivities. In this context, presuming data reflects the internalisation of cultural obsessions with "finding the self", "finding happiness" and "finding health" with a view to managing it better via data-driven modes of knowing.

But who is this self that emerges from self-monitoring actions? And perhaps more importantly, how did this self come voluntarily to the task of self-monitoring? And yet how and why have numbers become, for these individuals, the privileged way of becoming present to themselves? Where does their usefulness and authority come from as self-analysis tools? It is around these questions that this thesis is constructed. Throughout it, we hope to highlight how self-monitoring practices describe what the body, health, and its relationships to subjectivity are. We understand that self-monitoring is a way of becoming subject, of choosing and shaping action on oneself and of assigning meaning to suffering, to one's own existence and to one's own body. The result is an understanding of the phenomenon of self-monitoring as a response to the demands for risk management and performance optimisation. In this way, the vertices where the practices of the government of self-intertwine with the government of others are drawn.

Within this context, mHealth applications, together with the QS movement and gamification strategies, are constantly changing people's relationships with their own bodies. If people's bodies are data, can they become machines? Is there a symbiosis between bodies and technologies? Are people becoming digital cyborgs? What is the role of gamification in this context? With this in mind, the main objective of this chapter is to analyse the proliferation of mHealth applications as ways to promote and illustrate a permanent system of monitored bodies in the contemporary society. How does gamification and mobile technologies contribute to the creation of the digital cyborg? In order to address this question, we start by conducting a critical review of mHealth in contemporary society through the lens of self-monitoring, biopower and control. This review is followed by a critical analysis of elements from popular running apps (e.g. *Nike+*, *Runkeeper* and *Fitbit*) that could support and define a digital cyborg. The main contribution of this chapter is the analysis and definition of the movement of *datification* and the *digital cyborg body* from the perspectives of gamification, self-monitoring and mobile technologies.

The current chapter provides not only a guideline for the understanding of the perspectives of self-monitoring in future research but also discusses the main theories behind QSs in the contemporary society. We live in a society that is based on

mediatisation. The role of media in communication has become a basic practice of how people construct the social and cultural world (Couldry 2012). The use of social media, in this case, is understood in an inclusive way, including, for example, practices of self-knowledge based on wearable media and apps. Beyond this overall context, the term practice mainly refers to how different forms combine to build a more complex and socially situated pattern of interacting with media. Here we can think of the practice of mHealth, which involves different forms of personal data representation in online platforms, certain forms of searching in these platforms, other characteristic forms of online shared personal data and so on. Therefore, the term practice emphasises the social embedding of a set of communicative forms as well as their relation to human needs. In a society of control, as we will demonstrate, data, digitisation, technologies and the media have rebuilt the process of subjectivation, sociability, power and knowledge but also the senses of health and the practices of self-care. In the discourses and practices of digitised health promotion conditioned by the mediatisation of society, health risks have become increasingly individualised and viewed as manageable and controllable if lay people adopt the appropriate technologies to engage in self-monitoring and self-care. However, this is not enough; lay people must adopt a healthy lifestyle through the use of mobile health technologies like running apps. With the advent of the vast amount of data produced by digital technologies and the use of sophisticated algorithms to manipulate these data, it has become ever more convenient to focus attention on personal responsibility for health states.

As we will show, our society is transformed by the logic, technologies and discourses of the media. The increasing mediatisation we all experience nowadays has changed the exercise of biopower, in a very different way from the one analysed by Michel Foucault (1975).

3.2 mHealth and Bodies in a Society of Control

Michel Foucault (1975) described two dimensions of *biopower*. The first one refers to the administration of bodies, which are considered as machines by articulated mechanisms of disciplinary powers. The second one is related to the management of life. This second dimension shaped the concept of *biopolitics*, in which the human body is considered as part of a set of standard practices. Foucault reveals a significant level of functioning of the iniquitous political relations in contemporary societies. As stated by Foucault, there is a power technology centred on the body, which produces individualising effects through manipulation of the self.

Biopower refers to the practice of modern states and their regulation of those who are subject to it by means of an explosion of numerous and diverse techniques for subjugating bodies and controlling populations. In the European societies of the eighteenth century, new technologies of power arose. It is the physical bodies of people, the first space in which a new form of power has been exercised (Foucault 1975, p.17). This occurs with the institutionalisation of schools, hospitals, barracks,

prisons and other environments called "kidnapping" institutions. This domination is exercised by the use of disciplinary techniques to make tasks people more interesting. Besides disciplinary power, a type of power nominated by Foucault, biopower, appeared in the eighteenth century.

It is in the context of these societies that disciplinary power arises, born of a technology of power that treats the body of man as a machine, aiming to train it to transform it into a useful tool for economic interests. Concomitantly comes biopower, whose focus is not the individualised body, but the collective body. Biopower does not differ only from disciplinary power but also from sovereign power, for while in sovereignty there was a right of the sovereign to "let live" or "live" and the "letting die", which will be a power that will take care of the preservation of life, eliminating everything that threatens the preservation and wellbeing of the population. However, a disciplinary technology is not only centred on the body, but on life. Biopolitics is a technology that brings together the effects of living in a population and being an individual, seeking to control individuals as a group. Biopolitics aims to provide not only individual training but also an overall balance between disciplinary and biopower, such as a homeostasis that sets the security in relation to its internal dangers.

Disciplinary technology identifies the body as a set of capabilities to be developed. From the end of the seventeenth century, during the eighteenth century and especially in the early nineteenth century, this disciplinary technology developed and structured a completely new use of power technology to turn the body into labour forces. Such technology would be organised primarily around the discipline, that is, the technical process unit by which the body's strength is with minimal burden reduced as a political force and maximised as a useful force. Factories, schools, hospitals, hospices, prisons and other key institutions in the life of the capitalist industrial society are structured through operating logic techniques and tactics from this disciplinary process. Thus, this suggests that there is a new relationship between power and bodies. The human body transforms itself into a machine of power that scans, dismantles and reassembles the whole body. This discipline makes the bodies more submissive and docile (Foucault 1975, p.126). Therefore, in this context, it is possible that strategies such as gamification could provide a more ludic and pleasant way for people to deal with tasks.

We understand that since the last quarter of the twentieth century, our society has experimented with a notion of power based on a transformation from discipline to control, as formulated by Gilles Deleuze (1990). According to Deleuze (1990), this control takes place through power modelling and constant change. The control language is numeric and digital, since what matters is the access to information. Thus, this power is reinforced through a continuous information flow and instant communication. According to Deleuze, no one is more than a mass-individual pair. Individuals have become "vidual", divisible, and the crowd has become samples, data, markets or database. This control logic also sets the capitalist speed coupled with technoscience. With this, control becomes short term: it is not only about constant vigilance but also a continuous and unlimited possibility to locate something or someone (i.e. tracking). Power relations are injected and reinforced by

techno-scientific innovations, which start to cover the entire social body without leaving anything out of control. The focus of the post-disciplinary regime of power is to produce the appropriate individual, as technologies of modulation contribute to the individual desire to be autonomous, flexible and adaptable. The range of biopower is magnified, extrapolating institutions and specific areas and spreading to spaces, times and people's lives. Deleuze (1990) noticed a general breakdown of all sites of confinement that were a reflection of the characteristics of the disciplinary regime. These characteristics are transformed into a condition of permanent modulation, which comprehends wages, markets, time, labour contracts and human beings alike. Thus, societies of control become a result of conditions of constant meta-stability, which demands adaptability according to ever-changing conditions.

Although advances in biotechnology are not accessible to all individuals, there is a tendency to control and track information about the body itself. One of the most common examples of the use of communication and information technologies associated with healthcare is the monitoring of information regarding dietary intake and exercise routine through smartphones. In the context of the healthy lifestyle imperative, mobile communication devices gain importance by enabling the production, recording and consumption of information in real time. Thus, there are several applications, such as *MyFitnessPal* and *GAIN Fitness*, which offer nutritional diets and physical training programs based on individual data – such as sex, age and weight – and their goals (e.g. weight loss or gain of muscle mass). *MyFitnessPal* is an example of a mostly manual physical activity record that requires the user to enter all the data manually. *Runkeeper*, *Endomondo* and *MapMyFitness* are examples of mobile phone apps that require the user to specify when they are starting a specific activity but then automatically capture duration, speed, location traces and other details about the exercise bout. *Fitbit*, *BodyMedia FIT* and *Jawbone UP*, for example, are devices that a user wears all day (Andrew et al. 2013).

Fitbit has several models. *Fitbit Flex* and *Fitbit Force* are bracelets, while *Fitbit Zip* and *Fitbit Ultra* are attached to a garment as a clip. The main differences are in the presence of a display (which only the *Force* and the *Zip* have) and in collecting data on the number of steps that the person has climbed on a day (that only *Ultra* and *Force* provide). In all cases, focus is predominantly sports practice, and the synchronisation of the data collected by the bracelet can be done on an online platform or through a smartphone application. The functioning of the devices is based on the search for the transformation of daily life, operationalised by counselling, celebrating achieved marks and sharing results with friends. The idea is to do a little every day, making health defined as a set of habits and lifestyles. In this sense, these devices present themselves as products capable of promoting an adequacy that is both physical and subjective and which, as Rose (2000) advocates, takes the body as part of an identity and self-actualisation project in the task of being and becoming someone.

The bracelet also calculates calorie expenditure in a personalised way, considering age, height and weight of the user, along with the intensity and duration of physical activities. In addition, it allows you to add nutrition data that can range from a simple photo of each meal to detailed nutrition information that can be

provided by the user manually or by using the barcode of the product consumed. Therefore, we see, how the creation of computerised systems for other purposes ends up allowing unusual convergences with the devices of capture and registration of biometric data. *Fitbit* uses a more health-centred discourse. On the front page of the product site (www.fitbit.com) are the goals it can help its users achieve: to become more active, to feed themselves better, to manage their weight and to sleep better. The strategy of selling the product consists of presenting it as that which can connect the "desired self" to the "present self". Everyone can be healthy, happy and perform at their optimum levels, as the following sentence on the homepage of the site illustrates: "*Fitbit* motivates you to achieve your health and fitness goals by tracking your activity, exercise, sleep, weight and more".[2] An unreachable normality – since it tends to always want more – seems evident here. At the same time, however, such normality is presented as a democratic project, within reach of all overwhelmed contemporary individuals: "A morning jog, a walk during lunch, taking the stairs – these small changes add up to make a big difference. Taking just 10,000 steps a day, as recommended by the American Heart Association, can lead to a healthier you. No matter how busy your schedule, Fitbit helps you make fitness part of your daily routine".

MyFitnessPal takes a similar approach. Recognising that monitoring meals and physical activities can be tedious and difficult, it presents itself as a system that "learns from you".[3] The situation is similar for applications like *Lose It!*,[4] which includes weight loss goals and also the option to maintain weight, but does not accommodate those wishing to increase their body mass index.

It is interesting to note that, while focusing on a specific health goal, most self-monitoring applications and systems tend to extend support for this primary goal by tracking other variables or connecting the application to other devices that allow the user to gather more and more indicators about their health. *Lose It!*,[4] which advocates a vision of holistic wellbeing, claims to know that for its users, "weight loss is just one facet of your larger wellness goals". It states that we tend to consume the same foods, and that's why the application system remembers what you've eaten in the past, making the registration task easier. Similarly, it has a physical exercise database that helps users estimate caloric expenditure.

The evolution of digital technologies in the field of health, however, allows us to explore the data constantly emitted by the human body in a deeper way, tracing information that in the past we could obtain only through medical examinations. Wearable devices can go beyond the basics of calorie counting; they can measure mental and psychological states, for example. In this sense, Rettberg (2014) comments that the possibility of measuring information gives the impression that we can control them, like the data on productivity and health that we can strive to improve. In the context of wearable technology, there are a variety of products for this purpose available on the market. They are used as wristbands, necklaces or stuck in

[2] Available at www.fitbit.com/story.

[3] Available at http://www.myfitnesspal.com.br/welcome/learn_more.

[4] Available at https://www.loseit.com/how-it-works/.

pockets and synchronise with websites or smartphone apps, where graphics are generated and averages calculated. Thus, the combination of data generated through wearable devices and online services has led to an increased interest in tracking and analysing personal data. Such interest is not driven only by technology: "society in general is increasingly invested in quantitative measures that we hope will allow us to improve our performance" (Rettberg 2014, p.64).

3.2.1 The Quantified Self (QS) and Biopower

According to Swan (2013), one of the contemporary trends in the science of large volumes of data is the emergence of the "Quantified Self (QS)": the individual engaged in tracking any kind of biological, physical, behavioural or environmental information about himself/herself. In fact, this is a term that goes back to the general progression in the history of mankind of using "measurement, science, and technology to bring order, understanding, manipulation, and control to the natural world, including the human body" (Swan 2013, p. 86). Thus, health is often quantified. Objectives may range from tracking the resolution of some pathology to improving physical and mental performance. Consumers can, for example, track data on their weight, diet and exercise routine to factors such as blood pressure, glucose levels, sleep patterns and headaches.

The quantification of health has several implications for public health: first, it makes health a matter of quantitative performance (raising or lowering indexes, meeting goals, achieving goals); secondarily it disregards social, cultural, economic, infrastructural, environmental and social factors. Complex biological processes are involved in determining health and disease, and it makes health a purely individual rather than social and a collective issue to avoid the risk of becoming ill or worsening one's own health (Lupton 2016a, b). The idea of improving or worsening health is characteristic of this process of health quantification, which did not begin with mobile health technologies, but was deeply influenced by the way in which quantification is associated with the production, recording and transmission of personal health data.

According to Foucault's perspective on biopolitics and the disciplinary and normalising functions of the medical gaze, sociologists have written about the surveillance strategies that operate in the context of the clinical and the medical encounter (Armstrong 1995; Lupton 1997). In any case, the innovative standards of self-monitoring engendered by digital technologies are exposed to the hierarchical panoptic push matured in Foucauldian theories of castigatory criticism techniques in what has been termed a "post-panoptic" conjunction (Adams 2012). Technologies such as solutions for self-tracking belongings recognise that users hoard things in miraculous countless and fantastic ways. The power for self-monitoring offered by unsettled digital information accordingly configures a possibility pliant of reflection range which is chosen rather than imposed, seeming absolutely than nigh unto (Lupton 2012; Rich and Miah 2009).

Rather than a small number of hidden observers watching and monitoring many others, as the Foucauldian metaphor of the panopticon has it, the new digital technologies directed at promoting health often depend on individuals turning the gaze upon themselves and then inviting others to participate in their own surveillance by sharing the data (Lupton 2012). This is a version of the synopticon model of surveillance, where instead of "the few watching the many", the "many are watching the few" (Doyle 2011). Indeed, as stated by Lupton (2016a, b), since more and more personal information is uploaded and shared on social media, people also "watch" each other. It has been argued that the way we usually use the mobile health devices contributes to reinforce the centrality of "confessional" (Beer 2008) and of the "sharing" (John 2013) in our culture, in which it is expected that intimate and mundane aspects of one's life are constantly shared with others, including those that may previously have been kept private.

Although recording a memory or writing a narrative could evoke different emotions in the author/reader, the digital data produced by mobile apps is not only a support for self-reflection and action, but it is determined by activities and by interactivity. Interactivity is the principal value and rule of contemporary technoculture (Sodré 2002; Véron 2014). In this context, these apps are not a form of self-representation in the same way as self-portraits and journals, and wearable technologies preserve and present images of us through the data, which are very precise and narrow regardless of whether they are step counts: heart rate, productivity, location and so much more. All that information could be shared on social media, such as Facebook and Twitter. There are also apps that support communities or groups, creating their own social media network or associating with others. It is common that the users share their experiences of using apps through social media and online groups.

3.2.2 Gamification and Biopower

Gamification is a design strategy that influences people's behaviour and motivates individuals to perform an action, transforming boring situations into gameful and fun environments (Deterding et al. 2011). When considering the relationship between power and individuals' bodies, gamification could modify the relationship people have with disciplinary technologies.

The majority of mHealth applications include gamification in their core design strategy. For example, setting up personal goals, participating in challenges and the presence of competition with other users, badges, rewards and avatar representations could motivate users to perform healthy behaviours, such as losing weight or doing more physical activity (Marston and Hall 2015). This not only illustrates the influence of gamification in individuals' behaviours but also shows that gamification can facilitate biopower, converting disciplinary actions into a game. Yet, this concept could be criticised as exploitation ware or a way to use gameful elements to

mask undesirable behaviours (Bogost 2011). Thus, the main challenge when dealing with biopower and gamification is to understand who has control over the action. Who has the power to change individuals' behaviour? Briefly, the main outcomes of gamified systems for health promotion and sickness prevention include the ability to set and control personal goals, self-monitoring and self-reward (Payne et al. 2015). In other words, gamification can be employed in order to provide feedback loops and incentives to users. This aspect shows that the use of gamification for mHealth applications is centred on the self.

Nevertheless, the main challenge of gamification employed in mHealth applications is that it relies on the ownership of the body. For example, gamification has been criticised as a strategy that might overlook the abilities of users to effectively perform their desired behaviour (Lister et al. 2014). This suggests that gamified applications could tend to focus on the behavioural outcomes and incentives instead of the actual journey that users need to undertake to perform particular actions. Although these are important points to reflect on when dealing with gamification and the sense of control that users have upon their bodies, the current chapter will focus on the game design elements utilised in gamified mHealth apps that could transform bodies into digital cyborgs due to this sense of control.

3.2.3 Self-Knowledge and mHealth Applications

In his work on self-care practices in Western societies, Michel Foucault (2003a, b) discussed the underlying logic of technologies developed by man in order to obtain self-knowledge. The digitalisation of writing tools and the popularisation of mobile media evoked new questions, like economic values and organisational, moral, ethical and implicit political systems. Digital technologies of continuous personal monitoring interfere directly in the process of recollection, analysis and information feedback. Each digital record suffers direct influence of the action programs that guide the operation of the new media.

It is often only when we experience symptoms of a disease or notice changes in medical examination results that we care about and reflect on eating habits, physical exercise or any other preventive measure that would prevent the illness that has affected us. One of the widely valued possibilities for wearable media technologies is that self-care does not have to rely on medical equipment and computers nor expect the onset of symptoms to collect and analyse the data that our bodies emit. That is, we wear the sensors that gather this information and visualise them on smartphones. This ability will reduce health spending because it will reduce the need to buy drugs, get tests and consult doctors frequently: doctors will be able to monitor our data and call us for a consultation only when they identify some abnormality occurring within our body. Of course, this increases individual accountability for health.

An example of the use of wearable technology as prophylactic technology is the *Spire* device. Attached to clothing by a clamp, the sensor identifies changes in the

users' breath and sends a notification to his smartphone; if it recognises tension or stress in the way the subject is breathing, *Spire* suggests the user stops for a few moments and takes a deep breath, until it identifies that the users' nervous state has returned to normal.

NuvaRing, on the other hand, is not properly a preventative health wearable, although it also allows the wearer to have greater control over the phenomena that occur within their own body. This device consists of a ring inserted in the female sexual organ, able to track changes in her fertility cycle through body temperature and, when she identifies the most fertile period of the user, sends an alert to her smartphone. In fact, the technology empowers the woman, since it gives her greater control over the decision of when to conceive a child. The app helps women to remember to use the contraceptive *NuvaRing*.

There are also pregnancy and parenting apps. *BabyBump Pregnancy Pro*, for example, includes a community forum and a pregnancy journal to track your weight and the size of your baby bump. It even has a library of baby names to choose from, along with a handy birth planner. *Full Term* provides a track of labour contractions, in which pregnant women can track the start and end of each contraction. The app is designed to keep track of the times, durations and frequency of the entire labour period. The user can even email her own contraction history to a healthcare professional or keep it for herself for her own records. It also provides a weight tracker. *iHomeopathy* is an example of parenting apps. It gives the user a guide to treating first-aid emergencies, childhood ailments and common illnesses.

The changes that are currently occurring in relation to health and understanding of what it means to take care of health are clear. As Swan (2009) shows, the responsibility for this aspect of human life has already been considered an effort mainly attributed to trained and licenced health professionals. However, the ease of access to information related to this field, possible through communication and information technologies, as well as the citizens' interest in obtaining greater knowledge and control over this aspect of their lives, stimulated the formation of a network of exchange of health-related information, in which it is possible to connect the laity, professionals and public and private institutions concerned with exploring issues related to this topic.

In the scenario of the quantification and digitisation of the health, the choices are restricted to follow the norms, which became something like the goals, and specific numbers, to make sure that one has attained "good" or "perfect" health. Of course, there are numbers of uses of mobile health that provide better life and alternative treatment for patients. But there is also an industry of health. Some health apps are more concerned with selling an idea or an illusion of "perfect health", free from risky factors, diseases and suffering, in a way that makes people desire to maintain or develop a healthy lifestyle (Sfez 1995). Of course, these discourses on health are not new, but are related to the emergence of a health promotion model.

For Lupton (1995), the term health promotion is generally used to describe specific activities directed to goals, with a strong emphasis on rational management of population health. The major emphasis of health promotional rhetoric is on stimulating "positive health", preventing illness rather than treating it, developing

performance indicators based on specific goals, using the media to promote certain ideas of life behaviours and life attitudes associated with some products rather than focus on working with communities, encouraging their participation in propositions to develop healthy environments and reducing the growing expenses in healthcare. Hence, in this context, the control of the risks related to lifestyle tends to follow the same rationale, often being presented as something related to the private sphere and to the responsibility of the individuals, posed in terms of behavioural choices. However, it is important to consider some of the benefits of these approaches. There are undoubtedly positive health effects for people who may eventually change their risk exposure patterns through so-called behavioural changes. These changes, for example, can be achieved by using mobile digital technologies, as we are showing. On the other hand, it is necessary to observe that the generalised practice of production and consumption of these technologies has been consolidating an individual-based health vision and deepening certain tendencies of a control society.

Considering this, the contemporary social function is given in terms of the function of the market and technological vectors. As Deleuze remarks, in this context, capitalism ceases to be directed to production and becomes centred on sales, market and consumption: "Marketing is now the instrument of social control" (Deleuze 1990, p.180–181). Thus, there is a constant tension between the assertion of freedom of choice and the normalisation (or standardisation) of individuals. For example, we are always required to participate, to enter, to play, to share, to post a picture and to be checked, evaluated and corrected in the system of digital communication of health applications. This is quite revealing of how contemporary individuals are strongly characterised by incessant moratorium, never to be finished, free from the power. While freedom is a general principle in contemporary societies, responsibility for health is increasingly seen as an individual matter. We are experiencing what Rose (2000) calls the technologies of freedom:

> As far as individuals are concerned, one sees a revitalisation of the demand that each person should be obliged to be prudent, responsible for their futures and providing for their own security and that of their families with assistance of plurality of independent experts and profit-making businesses from private health insurance to private security firms (Rose 2000, p.324).

So, technologies of freedom have been invented to improve self-awareness regarding responsibility for individual choices and their consequences. For this unstable model of identity construction, there is the idea that one can choose lifestyles within the dominant sociocultural menu of choices. However, this choice is a form of normalisation and control of bodies by dominant discourses, knowledge and powers in the field of health and the media. These applications act as an axis in the constant search for self-ordering made available by the prevailing environments, where there is a proliferation of goods and merchandise being produced, high circulation in the distribution sector and inevitable frenzy at the point of consumption. Its use is a way of responding to the contemporary need to be always alert in relation to food, body, weight and risks. There is a much greater sense of constant debt to the body and health as a performance measured by numbers.

The next section of this chapter shows the main components of mHealth applications that could transform individual bodies into digital cyborgs, particularly through design elements that could provide a sense of control to users over their bodies, considering gamification and Quantified Self (QS) components.

3.3 mHealth Running Apps and Components

This section describes the design components related to mHealth applications, gamification and features that could provide a sense of control for users over their bodies. The objective of this section is to identify and explore the design factors embedded and incorporated in mHealth applications that collaborate for the creation of a digital cyborg.

3.3.1 Gamification Elements

The employment of gamification for health through applications has been previously investigated through a literature review of gamification principles for chronic disease management (Miller et al. 2014), a review of fitness applications (Lister et al. 2014), a systematic content analysis of behavioural theories in physical applications (Payne et al. 2015) and an illustrated review of gamification components that could be integrated into applications for health promotion and wellbeing (Marston and Hall 2015).

According to Payne et al. (2015), there are at least nine gamification design elements that could be used to motivate users to change their health behaviours. Those are the employment of a storyline, the existence of a fantasy environment, competition with other users, the possibility of failure, the presence of leaderboards, scores, ranking, levels and real-world prizes (Payne et al. 2015). For example, in their analysis, Payne et al. (2015) found that *SuperBetter* (an application designed to improve individual's wellbeing through resilience) was the most effective application, since it included all the gamification elements. *SuperBetter* has a surrounding narrative, illustrated by the words and language utilised in the application. The utilisation of words like "activate power" or "load power pack" shows an invisible but present storyline, as users could become their own super heroes. This could be one way to involve users in a task and build emotional links with their own actions.

Other gamification elements are setting up goals, social engagement, challenges, competition through leaderboards, badges and rewards, levels, app customisation and personalisation, feedback, role-playing and transparent tracking environments (Marston and Hall 2015). For instance, customisation can include the users' ability to choose and create their own avatar and change a simple aspect of the interface design, such as colour, font and background (Marston and Hall 2015). This aspect

could give a sense of control to the users, as they can personalise their own digital environments, bringing their own personality and taste.

Furthermore, it is important to mention that badges and rewards are concepts that might overlap as they could be treated from the same perspectives. Points, achievements, badges, medals, visual elements like animations, likes from friends and virtual gifts are examples of rewards in gamified applications (Lewis et al. 2016). In other words, rewards are incentives that keep users motivated, which could be digital or real, like real-world prizes and money, for instance.

Lister et al. (2014) also presented similar elements to Marston and Hall (2015) in terms of social influence; however, the difference was that the pressure from peers (e.g. family and friends) should also be considered as a social engagement, which could help to motivate users to change their behaviour. For example, family members could be extremely active, giving comments, advice and rewards for users in the application and in real life.

Similarly, Miller et al. (2014) also mentioned that badges, leaderboards, points and levelling-up, challenges and social engagement are the main gamification elements that could be used to enhance self-management. After a review of gamification elements, Miller et al. (2014) argued that challenges and quests are extremely important as they can be incorporated by other elements, such as badges, functioning as small steps to achieve a bigger goal. This shows that, if well integrated, gamified applications for health could enhance the potential of the bodies, augmenting the relationship between power and control that users have upon them.

3.3.2 Level of Control

As mentioned previously, biopower is a concept that relies on power and control over our bodies and lives particularly through a disciplinary technology. There is, though, a transformation that shifts the focus from discipline to control. Thus, in this section, the level of control from the perspective of design represents the capability of the mHealth applications to provide a sense of control to the users over their bodies through aspects like tracking and monitoring. This could be controlled by the user or by the application. For example, *MyFitnessPal* requires that users log their own data manually, whereas *Fitbit* can use mobile phones or other wearables as sensors that provide user's data automatically.

The capability of the mHealth application to provide a sense of control for the user is crucial when considering gamified environments. For example, gamification should support user participation in the whole process (Huotari and Hamari 2012). Payne et al. (2015) argued that the possibility of setting personal goals, self-monitoring and self-reward (e.g. gifts, treats, personal wellbeing) structures could be considered as outcomes of health behaviour. In other words, the application should support users while performing actions of self-control and self-reward. For example, the ability to customise personal goals and the digital environment, together with the capability to visualise personal data, are design elements that

support self-monitoring and self-reward. Therefore, for the analysis of the level of control, we searched for design elements that could augment goal-oriented actions, self-monitoring and self-reward.

3.3.3 Mobile Features

Pagoto et al. (2013) evaluated technology-related techniques for weight loss apps, which included a food barcode scanner, social media integration, reminders, calendar, tracking and diary recording (e.g. voice, photos, text). For example, users could connect their applications with social media networks such as Facebook and Twitter and post their achievements online, which could provide likes and encouraging comments. In fact, the integration between social media and health apps could not only reinforce social cues but also combine data from the application and data from the social network. Another strategy mentioned by Pagoto et al. (2013) was the incorporation of reminders. For example, users can set up their own reminders for the time to eat their meal or exercise. Such reminders could function through email or mobile alerts, depending on the application.

Another aspect to be considered is geolocation. This is a similar feature to that adopted by the early mobile app *Foursquare*, which utilised geolocation data to provide badges to users, rewarding their loyal behaviour (Zichermann and Cunningham 2011). Another use of geolocation for mHealth applications is through game-like mechanics, like treasure hunt and collection of items based on users' location, reinforcing physical activities (Boulos and Yang 2013). This could be very beneficial for mHealth applications as users could receive real-time notifications based on their location, becoming more pervasive and part of their reality. In other words, geolocation features could enhance user experience, combining patterns of everyday life with digital elements.

3.3.4 Characteristics of the Self

The consistent monitoring and tracking of the bodies has transformed the way people deal with themselves through self-knowledge. This aspect is represented by the Quantified Self (QS), in which people can measure their body performance through sensor activity. For example, it is possible to control users' posture through the monitoring of particular positions, which could be transformed into equations, neural networks and digital maps (Van Diest et al. 2015). That is, in order to identify the characteristics of the self, it is crucial to understand the design elements of mHealth applications that are capable of monitoring and quantifying the self. To investigate this, we borrowed features from applications that sustain the QS. For instance, Lupton (2013) has proposed that the presence of indicators could inspire self-knowledge. Blood glucose levels, energy, mood, body temperature, heart rate and

physical and brain activity are a few examples of indicators that could inform users about their body performance. Thus, in order to analyse the elements that could quantify the "self", we explore the indicators that could promote such knowledge.

Considering this, in the next section, we will utilise the four categories mentioned in this section: gamification elements, level of control, mobile features and the characteristics of the self to analyse how design elements can augment the digital cyborg.

3.4 Running App Analysis and Health Optimisation

The aim of this section is to provide an understanding of the design elements from mHealth applications that augment and sustain the digital cyborg. In order to explore such elements, we borrowed elements from gamification, mobile features, aspects that could give a sense of control to users and the capability of applications to quantify users' data.

3.4.1 Method and Sampling Strategy

In order to analyse the design elements that could enhance the transformation of bodies into digital cyborgs, we utilised the elements explored in Sect. 3: gamification design elements, level of control, characteristics of the self and mobile features. For this analysis, our chosen sample was composed of popular running applications: *Runkeeper*, *Fitbit* and *Nike+*. The reason for this choice is related to the level of popularity of these apps in mobile app stores. For example, *Fitbit* was the top wearable device most utilised by American users in 2015 (Forrester 2015). Moreover, *Runkeeper* had 2.1 million of users in the USA in 2014 (Nielsen 2014). When looking for the most popular apps in the iTunes App Store under the category Health and Fitness, *Fitbit* was the top app, followed by *Nike+* and *Runkeeper*.[5] Thus, for the purpose of the current analysis, those three apps were selected, downloaded and tested by the researchers. In this sense, the running apps were selected for analysis in this chapter based on the link they establish between media, body and organisation, being particularly favourable to research of the mediatisation strategies operated in the new media ontology context (Finnemann 2014). In the words of Schulz (2004: 96): "Although the new networks and storage technologies allow a more individualised and decentralised media use, they are nevertheless subject to central controls restraining choices and modes of application".

[5] Search was undertaken in December 2016 at https://itunes.apple.com/us/genre/ios-health-fitness/id6013?mt=8.

3.4.2 Analysis

In order to identify and explore the design elements that could augment the digital cyborg from the constant monitoring of bodies, we searched for features from gamification, characteristics of the self, mobile features and the level of control provided by the running apps. Considering this, in order to summarise the identified elements, we produced a table with a comparison of the main features of the analysed running apps (see Table 3.1). In this section, we demonstrate and discuss how those apps produce forms of health optimisation and with it new forms of control over users' bodies.

We identified that all the apps analysed provide a connection with friends. This supports the idea that social factors, such as sharing information with friends and family in social media or competing against friends, could motivate people to keep active (Hamari and Koivisto 2013). *Fitbit*, for example, provided challenges that can be undertaken at different times of the week. However, those challenges were fixed and did not provide a high level of control to the user, as a limited number of people can participate in each challenge. The same happened with *Runkeeper*; however, more users could participate in the suggested challenges. If using *Nike+*, users were only able to create their own challenges. Thus, *Nike+* should be able to show users how to create their own challenges as this feature could impact on their level of control. In this case, while interacting with *Nike+* for the first time, users are introduced to tutorials, which could help them to learn how to use the application and set up their own challenges.

In order to provide integration between the apps and the real world, *Runkeeper* utilised contextual information, such as weather information, with the aim of providing a context to the user's data. For example, it is possible that a bad performance could be related to a rainy day, particularly if the user runs outdoors. This shows that technology can fit into people's lives, particularly if considering mobile characteristics (Bell et al. 2006). However, it is the user who makes the association and interprets the information shown in the application.

Another aspect provided by both *Runkeeper* and *Nike+* was the possibility to buy products online. For instance, *Runkeeper* provided tangible rewards, like discounts in their own online store for members who could finish a challenge on time.

In all apps, part of the feedback structure was associated with colour, such as green vs. red if the mission was accomplished. The utilisation of colour as a means of providing more information is a design strategy that could convey meaning to the user without the need for words or images. In other words, the information is implicit within the colour. For example, the colour red could be associated with danger (Crozier 1997). This also opens the possibilities to researchers to look at the role of colour as a symbolic element, particularly through the lens of semiotics (Eco 1976).

Semiotics is the study of signs, which usually stand for something (signifier) that has a representation for someone (signified) (Peirce 1991). In other words, semiotics is about representations and how people interpret these representations. That is,

Table 3.1 mHealth components from running apps

Components	Runkeeper	Fitbit	Nike+
Gamification elements	Fantasy environment, competition, leaderboards, possibility of failure (e.g. non-completion of challenges), social engagement (e.g. share achievements with friends), clear goals, score, ranking, challenges, rewards, feedback, real-world prizes (e.g. discount on products), visualisation of progress	Fantasy environment, competition, possibility of failure (e.g. non-completion of challenges), leaderboards, social engagement (e.g. share selected achievements with friends), clear goals, ranking, challenges, badges and rewards, feedback, visualisation of progress	Fantasy environment, competition, possibility of failure, leaderboards, social engagement, clear goals, score, ranking, levels (e.g. beginner, intermediate, advanced), challenges (e.g. create your own), feedback
Level of control	Set personal goals, self-monitoring	Set personal goals, self-monitoring, customisation of dashboard	Set personal goals, self-monitoring, create own challenges
Mobile features	GPS, geolocation, social media integration, notifications, integration with real world (e.g. map visualisation, weather integration and discounts)	Social media integration, tracking, geolocation and integration with the real world (e.g. map visualisation)	Social media integration, reminders, calendar, tracking, information recording (e.g. photos and notes), geolocation and integration with the real world (e.g. map visualisation)
Characteristics of the self	Presentation of challenges in the system (the need to overcome challenges/obstacles); meeting the challenges gives discounts on products of *Runkeeper* online store (performance as a reward); the limitation of freedom of choice (users are always challenged by the system); system rhetorical notification in order to achieve goals ("Are you progressing?"); publication of achieved goals in social networks (exposure as a reward and competition with other users)	Nutritional information and measurement of progress by means of a progress bar that indicates the colour development of the users in their individual goals (the quantification of health and performance); challenges with other users (performance as competition); reward as trophies that can be shared on social networks	Customisation of goals through information setup (e.g. gender, weight, age, height, daily caloric intake); quantification of existence as a guarantee of high performance; system as a personal trainer; performance established at levels (beginner, intermediate and advanced); there is no reward or prize, but users can take pictures and add notes after the workout and share photos that carry the brand *Nike* on social networks (this allows brand enhancement and association)

colours, sounds, animations and forms could carry implicit and symbolic communications between the system and the user. For example, the applause when achieving a goal could represent not just the applause itself, but winning a medal after a competition. It is possible that depending on the user's background, the applause would represent a situation like being in a podium after winning a gold medal or just the applause after a good performance. In interactive systems, semiotics can be employed in order to explore the dimensions of the digital representations, not only in the interface level but also in the level of interactions (Andersen 2001). This shows that visual representations together with the tasks that users need to perform in the systems could make their experience more relevant. Thus, it is possible that gamification design elements could utilise colour and interactivity as design strategies in order to express implicit information to users.

This characteristic also reflects the propositions reviewed by Marston and Hall (2015), as graphs, texts and icons could be used as feedback strategies. However, these structures also showed a transformation of data. Additional feedback structures included data visualisations from previous or current exercises. Numbers, colour, animation, size and shape of the graphics and metaphors were the main design strategies employed in badges and rewards and data visualisation, such as graphs and tables. For example, in *Fitbit*, users could run the distance of a country or have their data compared to a "monarch butterfly migration", which could be employed in a badge. This aspect not only shows that illustrations and metaphors might give a ludic environment to the user, but it also shows an integration of design strategies, since data could be transformed into a reward. For example, users could be awarded a "monarch butterfly migration badge".

Furthermore, in all apps, leaderboards and challenges were the main strategies employed in order to support competition. Although this aspect could increase motivation based on social relations (Marston and Hall 2015; Hamari and Koivisto 2013), no option was given to users to be part of a team, for example. This suggests that those apps could improve in terms of cooperation and collaboration, as users could undertake challenges with their friends.

If considering Payne et al.'s (2015) components of gamification (e.g. storyline, fantasy, competition, possibility to failure, real-world prizes, rewards, badges, challenges, levels, ranking, score, clear goals, social engagement and leaderboards), the analysed running apps did not have a storyline. This could indicate an opportunity for developers to design more apps that could integrate the user's running environment, which goes beyond location. For example, if users want to start running because they want to run a marathon in a few months, the running apps could tell the story of their progress since the beginning through a narrative using fantasy cues, including characters (e.g. users, friends and family), environment (e.g. running scenario, weather, location) and achievements (e.g. badges and rewards).

All the analysed running apps supported quantified self-expressions, which could be understood as a personal productive efficiency. In other words, self-expressions could reflect a systematic governance of subjectivity that gives a certain security in the face of complexity, reducing and simplifying knowledge in order to make it manageable. According to Lupton (2014b), when the body is established as

a data repository, the presentation of it becomes a central issue for the concept of identity. According to the information generated by the system, the presentation of this data was designed in order to provide a deeper understanding and interpretation of the individual's body and habits. From this perspective, the degree of detail and picture fidelity itself therefore depended on the level of engagement and the amount of data produced by each user.

Based on the ideal of health optimisation and perfecting the self through the quantification and objectification of the body, the analysed apps offered an oriented system with continuous monitoring of daily activities. With regard to monitoring, a set of processes was designed in order to engage the user in the practice of personal records. Since the system was oriented to produce data, it utilised some procedural arguments, such as "use the device to enter the system" or "just leave the device connected to the body". Initial commands like these were also indicated in messages of encouragement displayed on wearable devices, phone notification systems and graphical interfaces. These notifications called upon the user to interact through the monitoring performance. Unlike apps that focused on the habits of control, these apps required an action that could meet the media procedure and self-written expressions enhanced by user data.

The system behind the wearable devices tended, therefore, to focus on the continuity of data collection. For this, the system captured events and procedures that do not demand user intervention. A bracelet, for example, could remain active, providing real-time feedback of the collected data, the mobile device monitored background activities and the system suggested competitive challenges and performances.

This continuous capture of data could convince users to keep the device on their body. Mobile monitoring operated as a redundant strategy, allowing the system to predict any gaps caused by battery failure or, in some cases, the non-use of the wearable device. This strategy introduced practices that are justified in the case of expansion of the systems' attributes, such as adding the location of activity via the phone's global positioning system (GPS), for example. Competitive performances also sought to ensure the maintenance of practices that could raise actions involving competition between users of *Fitbit*, *Runkeeper* or *Nike+* in social networks, which helped users to overcome personal goals.

Similar to input strategies, the procedural arguments focused on system maintenance and user engagement could be seen as processes related to the procedural nature of the media and expression of personal monitoring experiences. For example, passive recording invited the user to shift attention to the body activity, while the suggestion of challenges proposed the experience of overcoming certain objectives. Otherwise, the apps that we analysed called the user to remain engaged with a performance that produces data for the system. The system also suggested repeatedly supported behaviours as a way to improve self-knowledge and develop skills through exercises and continuous effort.

This repetition of practices and procedures, in turn, alluded to training programs conducted by a personal trainer. On the user level, visualisation tools could support the update of self-image, drawing from the data the objectification of individual

organic dimensions and processes. Thus, the analysed running apps could also operate as a repository of objective memory about the users' overall performance (Lupton 2014a). As Whitson (2013, p.175) notes, "quantification of the self allows us to replace the holes in our memories and the vagaries of our intuition" with the apparent objectivity and perspicacity of data-based knowledge, a techno-driven movement that makes instinctual powers of the body–mind progressively more peripheral and obsolescent as sources of enlightenment, awareness, edification and truth. In this deterministic turn to processes of externalisation and objectivation, knowledge of the body/self is only validated if it appears outside of the body/self, especially in the form of a multiplex data visualisation.

Data visualisation strategies could also function as *procedural rhetorical* mechanisms. These strategies invite users to make decisions about their own bodies. Developed from the concept of dashboards (i.e. information presented through a control panel format), the graphic interface is extremely dependent on user data. Without this data, graphics could not be created, the statistics do not make sense and programs for monitoring different aspects of the body remain dormant. Thus, at the information display level, the system makes use of procedural arguments, calling users to perform an action through words, alerts or just data visualisation. That is, users would feel persuaded to perform an action by just interpreting the way the data is displayed to them. Moreover, the visualisation of dashboards implies a hierarchy that extends user control over data repository variables, bulky and transient, allowing exploration of aspects and areas intuitively and without the need for specialised analytical skills.

In contemporary society, there is a passage from disciplinary surveillance analysed by Michel Foucault (1975) regarding this private risk management. In this context, individuals are urged to become managers of each other, planning their lives as online entrepreneurs, building strategies for their business, assessing risks and making choices that aim to maximise their quality of life, optimising personal and private resources and managing options according to cost-benefit parameters, performance and efficiency. Thus, contemporary subjects seek to assume the demands of competitiveness. Considering this, individuals' own health becomes a capital that people should manage by choosing the best living habits and calibrating the risks that may arise from them. This aspect reflects the business logic of change management and profit, for example. In running apps, individuals must demonstrate ability to adapt to changes constantly, utilising resources like monitoring and recommendations.

Contemporary equipment should be compatible with computers and a myriad of devices based on digital logic. Nowadays, equipment is permanently at risk of obsolescence, being challenged to maximise flexibility and recycling ability. Thus, the analysed running apps could contribute to produce the digital cyborg body as a contemporary requirement for the pursuit of high performance and a healthy lifestyle. The individual is reached by new *biopolitics modalities* of the imperative of health in order to become a manager of himself/herself, such as the idea that who cannot reach or exceed goals can be regarded as subhuman, unproductive and irresponsible (Lupton 1995). Thus, new knowledge and technologies bring to the mar-

ket a series of preventative devices that allow each individual to manage risks inherent to self-knowledge. Information becomes a key instrument of today's digital life.

The running apps *Runkeeper*, *Fitbit* and *Nike+* are, therefore, configured as preventative therapies, designed with the goal of controlling life, augmenting the development of the digital cyborg. The fact that individuals expose their exercise routine and diets shows a regime of visibility that transforms the individual experience of losing weight and getting fit. This experience would be different if it was restricted only to the individual's private life, since the mere fact of regularly exposing body weight and daily diet to friends and followers on social networking sites causes people to remain in a state of permanent self-control, which is maintained and continued by the control and expectation produced by exposure.

In this sense, we can argue that digital technologies, through various applications, function as an externalised self-awareness that allows individuals to make decisions based on the permanent monitoring of daily habits and the control and crossing of physical, alimentary and physiological data. With this monitoring, individuals can substantially improve their quality of life as the decisions taken today regarding health and wellness are reflected in a healthier future, with a greater control over diseases such as obesity, hypertension and certain types of diabetes.

We would thus be living the "unfinished revolution", which Dertouzos (2001) describes, with communication and information technologies more integrated into our daily lives. Self-monitoring is only possible once there are devices that allow sufficient mobility so that they can be brought to any place without difficulty and whose interface is friendly enough to produce constant information. Today's mobile devices, such as smartphones, are increasingly pervasive and integrated into our daily lives, on the way to "disappearing", as predicted by Dertouzos (2001). However, one of the consequences of having more friendly and imperceptible technologies in our day-to-day lives implies, as we have seen, a permanent vigilance regime, with its constant monitoring actions, which are becoming so much a part of our common practices.

Self-monitoring represents both a way of taking care of biological life and the instrumentalisation of decision-making processes in various areas of our daily lives. Among the Quantified Selves, we find individuals interested in optimising something simple, such as choosing what to wear each morning, as well as those who, although healthy, anguish about their normality or future, acting in the search to avoid ageing and death. Whatever the aim pursued, the constant that gives cohesion to the movement lies in the analytical attitude of its adherents: they give a scientific character to their actions, bodies and choices by asserting that the world has become too complex to act only on the designs of our own intuition. They show that taking responsibility for one's health and one's own success should be, in fact, a task of planning, producing knowledge and calculating. It is also a task of acceptance and challenge of established knowledge, which forces the boundaries between medical care and self-care. On the other hand, individuals are empowered and actively seek information and tools to position themselves where the instituted knowledge arouses controversy and doubt. In this sense, self-monitoring is challenging the knowledge

of the other, which involves, for example, measuring individual susceptibility, i.e. calculating your case rather than content to be allocated probabilistic ranges of risk stratification. On the other hand, Quantified Selves also appropriate the praxis proper to the domain of science to analyse their own behaviour and the body itself, comparing them with what the medical or pseudoscientific knowledge that circulates in the various counselling bodies to which they refer.

In contemporary society, risk is the counterpart of liberation. The most immediate consequence is the increasing accountability of individuals for their lives and their future, which exacerbates the need for the conversion of each into a calculating subject. Autonomy, then, emerges as imperative, a pattern against which deviations and deficits are measured and gain significance (Rose 2000). Its main consequence is the vulnerability to the demand to choose and to evaluate the innumerable possibilities that open to human existence. Choices need to have a scientific character, which can be objectified, placed in relationship and justified to themselves and to others, articulating responsibility and a reflexive consistency, which is based on the objectivity of numbers, graphs and spreadsheets. On the other hand, in the face of uncertainty about what, after all, good life is, life seems to stand out as a value itself.

3.5 Final Considerations

This chapter discussed the transformation of the body into data, enhancing the aspects that transmute the body into a digital cyborg. This was discussed through the analysis of mHealth running apps (*Fitbit*, *Nike+* and *Runkeeper*) through the lenses of gamification, quantified self (QS), control and mobile features. The results of this analysis supported the dichotomy between numeric and visual data as a way to represent the body in both virtual and real worlds. In fact, both worlds could merge into one, as apps and individuals are more integrated each time. Wearable devices, contextual information (e.g. weather information, maps) and real-world rewards could represent this connection. In this scenario, gamification reinforced such data transformation. For example, the completion of challenges and quests was only possible through the analysis of the data gathered during the running exercise. Runners were able to achieve their goals if their data was tracked or logged in the system. Thus, the presence of gamified elements like challenges and achievements needed to be integrated with the user data. Similarly, while interacting with the running apps, users could only compete with their friends if they had data logged in the system, which could be represented through points or badges and published in a leaderboard. This shows that gamification could function as an enabler of the digital cyborg, providing meaning to user data. In other words, gamification could help to personalise digital bodies, building a connection between the real and the digital world. This aspect not only helps to transform the digital cyborg, but it also provides a sense of control to the user. For example, users can customise their own digital environment while interacting with mHealth applications, such as

uploading their own picture, creating their own avatar or changing the fonts, colours and sounds of their digital interface.

Computing devices that are used on the body (i.e. wearable technologies) could also operate independently or attached to a smartphone. Wearable technologies, for example, could be used on the body (such as a smart tissue), around the body (such as a watch) or as part of the body (such as a sensor under the skin like a tattoo or a sensor connected to the heart that measures the heartbeat). In fact, it is possible that in the future, sensors could not only monitor but also surpass human capabilities. For example, in an article published in Wired UK (Enriquez 2016), there is technology available to build superhuman hearing aids that could focus on specific aspects of conversations. Wearable technologies could also function as accessories, being different from wearable computers. For example, it is possible to choose the colour of the *Fitbit* wristband, respecting people's colour preferences.

mHealth applications also collect and handle information in real time. Thus, the analysed running apps are part of the consolidation of a new scientific paradigm, possible in a society of control: *datification*. *Datification* is the transformation of social action on quantified data online, allowing real-time monitoring and predictive analytics (Van Dijck 2014, p.198). Thus, this new paradigm brings up the belief in the objectivity of quantification and the potential to track all kinds of human behaviour and sociability through online data. This concept can be called *dataism* (Van Dijck 2014), which is based on another old belief: that numbers bring objective truth. In the same way, data generated by self-monitoring devices such as racing cars are presented as a guide for the uncertain terrain of life and promises (Van Dijck 2014). Having this data objectified in a visual presentation, such as a chart or table, could help users to view what is going well and what needs to be improved, such as company managers. Thus, self-monitoring apps become effective tools for the individual who wants to be the "manager of his/her own life" (Ehrenberg 1991). This context highlights a major transformation upon the body, which could begin with the marriage between electronics and molecular biology: the establishment of a computer model, which is not only the human body but also the entire living universe that eventually converts all the complexity of life into information.

Wearable media (i.e. *Fitbit*, *Runkeeper* and *Nike+*) is also configured by a complex network of human (e.g. developers, users) and non-human factors (e.g. software, algorithms, manufacturers, servers). Each of these factors carries policies and values that are implicit in their action programs, constantly interfering in the way individuals and institutions update the concepts of health in self-monitoring routines. In fact, there are algorithms that could learn from the data, particularly through artificial intelligence and neural networks. For example, artificial neural networks could be employed in order to interpret and analyse complex data from human movements (Van Diest et al. 2015). This means that algorithms can learn from the data, model and predict actions. Thus, the analysis of self-monitoring practices using digital media must take into account the user's identity, the individual and collective perception about the body's own physical limits and the goals of self-care and self-optimisation.

The running apps analysed in this chapter could lead the user to perform in articulation to the output data. This articulation is a result of a computerised control system of self and the perception of the body, which could be enhanced by data visualisation. Moreover, the actions involving data visualisation of the self are configured by the contemporary moral that transforms the conception of health as an association between body, image, performance, goals and data.

Another aspect to take into account is data ownership. As mentioned by Lupton (2016a), hospitals are integrating the data from mHealth applications into patients' data in order to prevent illness and promote positive health behaviours to patients. It is possible that together with medicines, doctors would be able to prescribe mHealth applications to patients. Yet, data ownership is still a challenge in this context.

mHealth applications also reflect the contemporary culture that valorises the body. What differentiates the current somatic culture from others is not the amount of time given to body care, but the peculiarity of the relationship between psychological, moral and physical lives. Thus, it is possible that this ultra-valorisation of the body could blind users while dealing with data ownership. The culture of the body and the ideal of wellbeing generate increasing concern about fitness and health, and with it, the body could be directly influenced by technoscience in order to reduce failures. Every culture is a body culture, since culture involves training, maintenance and reproduction of physical and mental habits. The expression "body cultured" cult of the body, is not a definition of contemporary occidental societies; it is a focus. This inaccurate designation draws attention to the fact that the body has become a privileged reference for the construction of personal identity.

Body culture also engenders issues of happiness, beauty, self-esteem, prosperity and glamour. Hence, the contemporary body culture is related to fashion, lifestyle, aesthetics (in terms of physical appearance), cosmetics industry, dietetic food, plastic surgery and others. Body culture can also be related to a set of online technologies for monitoring the body's performance. The predominance of discourses and practices of self-care do not seem to have focused on curing diseases or correcting deviant behaviour. Instead, our culture spreads many possibilities of everyday discomforts, particularly through the medicalisation of the most trivial annoyances of everyday life and, above all, the optimisation of human capabilities in the search for a certain ideal of happiness and high performance.

In the current post-disciplinary regime of power, there was a transformation in the notion of health as a way to correct and normalise bodies and subjectivities, in order to understand health associated with body reprogramming and behaviour optimisation. Many individuals adhere to projects that optimise and improve their bodies, and supposedly their health, which can be supported by science, ludic systems (e.g. gamification) and contemporary biotechnologies. Therefore, technological advances like wearable devices, smartphones and gamified apps transform and transcend the human being. As Lupton (2012, p.14) stated, the digital cyborg body configured by mHealth technologies "supports a reflexive, self-monitoring awareness of the body, bringing the body to the fore in ways which challenge the non-reflexive, absent body". While the cultural imaginary of the cyborg sets an idea of

an embodiment of the self by machines and technological devices, the use of health wearable technology is a necessity for the biological body as a body that has to be monitored in order to be improved.

It is not possible to think about these changes in the human body, in the senses of health and illness and presence of mobile technologies in our everyday life, and not think about the processes of mediatisation. Mediatisation is characterised by the development of technological prosthetics of the sensible reality, altering our own experience with the body, with others, with motherhood, with paternity, with physical activity, with food, with illness, with relationships loving or sexual and so on. These applications document for themselves significant changes between the human being and technology. But they not only document; they participate actively in the process of transformation of lived reality, since they are media forms of reconfiguring the lived experience and conditioning it more and more to the use of technologies. As Sodré (2002) explains, the term prosthesis (from the Greek *prosthenos*, extension) does not designate something separate from the subject, in the manner of a malleable instrument. What McLuhan (1964) had observed in his seminal study was something like a complement or extension of human activities, organs and senses through communication and transport technologies (television as an extension of vision, the hearing telephone, the voice radio and so on, the feet wheel and so on). However, what we are experiencing today is a radical change in our experience of reality; it represents the resulting form of networked and wearable technology media and takes the form of a specular or spectral extension that ~~if~~ it inhabits, as a new world, with new ambience, own codification and suggestions of conduct. As Sodré (2002) comments, techno-mediations have intensified drastically in the last decade. They are more than technological devices because they are cultural values that constitute the moment in which the communication process is technically marketed and redefined by information, acceleration, connectivity, interactivity and performance.

Performance is an activity that includes showing oneself to the other, a process linked to the formation of contemporary subjectivities. Performance, therefore, refers not only to an observed, but produced, and displayed yield. It consists in a technology of quantification. Human performance is measured in terms of efficiency or performance. In this sense, the performance symbolises, fundamentally, the conversion of the qualitative into quantitative. The identification of characteristics of a system, a machine or a human being constitutes competitive advantages. It is precisely with this sense of calculation of predicates in competitive situations that the concept became central, in the last decades, both in the scope of the techniques of business administration and, more broadly, in the orbit of social discourses and subjective practices. The idea of analysing oneself for personal improvement already implies a comparative situation, which can be a competition when compared to the other, or an analysis of one's own evolution, which consists in comparing oneself with oneself. The field of self-monitoring equips subjects with measurement, calculation and management techniques so that they can make better decisions, take better care of themselves, make better use of their time, make better choices and finally achieve their goals.

From the examples presented in this chapter, it was possible to perceive that we live a reordering of the regimes of visibility and vigilance in the present, which implies a reorientation of the experience of the spaces in which we live and of the technologies that are part of our daily life. In this sense, digital mobile technologies, through various programs and applications, function as an externalised self-awareness that allows individuals to make decisions about their daily lives, from the permanent monitoring of daily habits and the control and crossing of physical, food and physiological. All this monitoring is made possible by the popularisation of digital mobile devices, the practical ones so that they can be taken to any place without great difficulty and with friendly interface enough for the production of information to occur from way.

Nevertheless, it is important to consider the demographic information about the user. Culture, age and gender backgrounds influence the way people interact with technologies. For example, older individuals have life experiences that could be used in their favour while dealing with mHealth applications (Maier et al. 2015). Particularly when dealing with health issues mediated by technology, the consideration of age is mandatory. Older individuals have different needs, such as the need to feel safe, remember short-term events and interact with easy and simple technologies (European Commission 2005). As mentioned by Maier et al. (2015), being old is not an illness; it means that older individuals have different needs and experiences. In addition, carers should not be overlooked when dealing with older individuals in health-related contexts (European Commission 2005). Thus, it is possible that when interacting with mHealth applications, carers could also participate in the process. For example, if the mHealth app includes gamification, carers could be part of a team, cooperating with the patient's family to help the individual to perform an action (e.g. remember to take a pill or remember a particular event, in case of dementia or Alzheimer's disease).

Considering this, it is possible that mHealth could go beyond self-monitoring and could promote more participative interactions. Still, the self-monitoring practice sustains the idea that something can be improved through a thoughtful attitude that includes measurement and analysis. This improvement often refers to the life condition of a chronic patient who has to cope with an illness, to try to bring his body closer to normal, eliminating present or future symptomatic effects that medicine knows little about or knows about statistical terms, rather than individualised ones. It is in this context that technological advances through machine learning and artificial intelligence, such as IBM Watson[6], could utilise this data to improve healthcare.

It is important to remember, however, that self-monitoring also aims at "better than well" (Elliot 2003), meaning that bodies are more than they really are and that more time is more important than well spent time. Hence, the boundaries between health, body enhancement and the choices we make in our daily lives become issues of high expectations.

[6] http://www.ibm.com/watson/health/.

Acknowledgements Vanissa Wanick gratefully acknowledges the grant from *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES), Brazil (number: 9520-13-9). Igor Sacramento gratefully acknowledges the grant from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brazil.

References

Adams S (2012) Post-panoptic surveillance through healthcare rating sites. Inf Commun Soc 16(2):215–235

Almarshedi A, Wanick V, Wills G, Ranchhod A (2016) Gamification and behaviour. In: Stieglitz S et al (ed) More than just games. Springer International Publishing, pp 19–29

Andersen PB (2001) What semiotics can and cannot do for HCI. Knowl-Based Syst 14:419–424. doi:10.1016/S0950-7051(01)00134-4

Andrew AH, Eustice K, Hickl A (2013) Using location lifelogs to make meaning of food and physical activity behaviors. In 7th international conference on pervasive computing technologies for healthcare and workshops

Armstrong D (1995) The rise of surveillance medicine. Sociol Health Illn 17(3):393–404

Beer D (2008) Researching a confessional society. Int J Mark Res 50(5):619–629

Bell M et al (2006) Interweaving mobile games with everyday life. In CHI 2006. ACM, Montreal, pp 417–426

Bentley F, Tollmar K (2013) The power of mobile notifications to increase wellbeing logging behavior. Proc SIGCHI Conf Hum Factors Comput Syst – CHI'13. doi:10.1145/2470654.2466140

Bogost I (2011) Gamasutra – persuasive games: Exploitationware. http://www.gamasutra.com/view/feature/6366/persuasive_ games_exploitationware.php/. Accessed 23 Dec 2016

Boulos MNK, Yang SP (2013) Exergames for health and fitness: the roles of GPS and geosocial apps. Int J Heal Geogr 121(12):295–305. doi:10.1186/1476-072X-12-18

Couldry N (2012) Media society world: social theory and digital media practice. Polity, Cambridge

Crozier WR (1997) The psychology of colour preferences. Surf Coat Int 80:577–585

Deleuze G (1990) Post-scriptum sur les sociétés de contrôle. In: Pourparlers, Paris: éd. De Minuit

Dennison L, Morrison L, Conway G, Yardley L (2013) Opportunities and challenges for smartphone applications in supporting health behavior change: qualitative study. J Med Internet Res 15:1–19. https://doi.org/10.2196/jmir.2583

Dertouzos M (2001) The unfinished revolution: human-centered computers and what they can do for us. Harper Paperbacks, New York

Deterding S, Dixon D, Khaled R, Nacke L (2011) From game design elements to gamefulness. In: Proceedings of the 15th international academic MindTrek conference on envisioning future media environments – MindTrek '11. ACM Press, New York, p 9

Dithmer M, Rasmussen JO, Grönvall E et al (2015) "The Heart Game": using gamification as part of a telerehabilitation program for heart patients. Games Health J 5:27–33. https://doi.org/10.1089/g4h.2015.0001

Doyle A (2011) Revisiting the synopticon: reconsidering Mathiesen's "The Viewer Society" in the age of web 2.0. Theor Criminol 15(3):283–299

Eco U (1976) A theory of semiotics. Indiana University of Press, Bloomington

Ehrenberg A (1991) Le Culte de la performance. Calmann-Lévy, Paris

Elliot C (2003) Better than well: American medicine meets the american dream. W. W Norton & Company, New York

Enriquez J (2016) Could we soon "upgrade" our bodies? Extreme bionics will create modular superhumans. http://www.wired.co.uk/article/bionic-limbs-make-us-superhuman. Accessed 28 Dec 2016

European Commission (2005) i2010 – A European information society for growth and employment

Finnemann NO (2014) Digitization: new trajectories of mediatization? In: Lundry K (ed) Mediatization of communication. Mouton de Gruyter, Berlin/Boston

Forrester (2015) Data digest: announcing our annual benchmark on the state of US consumers and technology in 2015 | Forrester Blogs. http://blogs.forrester.com/gina_fleming/15-09-28-data_digest_announcing_our_annual_benchmark_on_the_state_of_us_consumers_and_technology_in_2015. Accessed 26 Dec 2016

Foucault M (1975) Surveiller et punir. Gallimard, Paris

Foucault M (2003a) Self writing. In: _____. Ethics: subjectivity and truth. New Press, New York

Foucault M (2003b) Technologies of the self. In: _____. Ethics: subjectivity and truth. New Press, New York

Hamari J, Koivisto J (2013) Social motivations to use gamification: an empirical study of gamifying exercise. In Proceedings of the 21st European conference on information systems, Utrecht, Netherlands, June 5–8

Hamari J, Koivisto J (2015) "Working out for likes": an empirical study on social influence in exercise gamification. Comput Human Behav 50:333–347. doi:10.1016/j.chb.2015.04.018

Huotari K, Hamari J (2012) Defining gamification: a service marketing perspective. In Proceeding of the 16th international academic MindTrek conference (pp. 17–22). ACM

Istepanian RS, Woodward B (2016) M-health: Fundamentals and applications. Wiley, Hoboken

John NA (2013) Sharing and web 2.0: the emergence of a keyword. New Media & Society 15:167

Lewis Z, Swartz MC, Lyons E (2016) What's the point?: a review of reward systems implemented in gamification interventions. Games Health J 5:93–99. doi:10.1089/g4h.2015.0078

Lister C, West JH, Cannon B, Sax T, Brodegard D (2014) Just a fad? Gamification in health and fitness apps. JMIR Serious Games 2(2):e9

Lupton D (1995) The imperative of health: public health and the regulated body. Sage, London

Lupton D (1997) Foucault and the medicalisation critique. In: Petersen A, Bunton R (eds) Foucault, health and medicine. Routledge, London, pp 94–110

Lupton D (2012) M-health and health promotion: the digital cyborg and surveillance society. Soc Theory Health 10:229–244

Lupton D (2013) Understanding the human machine. IEEE Technol Soc Mag 32(4):25–30

Lupton D (2014a) You are your data: self-tracking practices and concepts of data. In: SSRN

Lupton D (2014b) Self-tracking cultures: towards a sociology of personal informatics. In: Proceedings of the 26th Australian computer-human interaction conference on designing futures: the future of design. ACM, New York

Lupton D (2016a) Digital health technologies and digital data: new ways of monitoring, measuring and Commodifying human embodiment, health and illness. In: Olleros F, Zhegu M (eds) Research handbook on digital transformations. Edward Elgar, Northampton, pp 1–16

Lupton D (2016b) The quantified self. Polity Press, Cambridge

Maier A, Özkil AG, Bang MM, Hysse Forchhammer B (2015) Remember to remember: a feasibility study adapting wearable technology to the needs of people aged 65 and older with mild cognitive impairment (MCI) and Alzheimer's dementia. In: Proceedings of international conference on engineering design, vol. 1, pp 331–340

Marston HR, Hall AK (2015) Gamification: applications for health promotion. Handbook of Research on Holistic Perspectives in Gamification for Clinical Practice, 78

McLuhan M (1964) Understanding media: the extensions of man. McGraw Hill, New York

Miller AS, Cafazzo JA, Seto E (2014) A game plan: gamification design principles in mHealth applications for chronic disease management. Health Informatics J:1–10. https://doi.org/10.1177/1460458214537511

Nielsen (2014) Hacking health: how consumers use smartphones and wearable tech to track their health. http://www.nielsen.com/us/en/insights/news/2014/hacking-health-how-consumers-use-smartphones-and-wearable-tech-to-track-their-health.html. Accessed 26 Dec 2016

Pagoto S, Schneider K, Jojic M, DeBiasse M, Mann D (2013) Evidence-based strategies in weight-loss mobile apps. Am J Prev Med 45(5):576–582

Pandian PS, Mohanavelu K, Safeer KP et al (2008) Smart vest: wearable multi-parameter remote physiological monitoring system. Med Eng Phys 30:466–477. https://doi.org/10.1016/j.medengphy.2007.05.014
Payne HE, Lister C, West JH, Bernhardt JM (2015) Behavioral functionality of mobile apps in health interventions: a systematic review of the literature. JMIR mHealth and uHealth 3(1):e20
Peirce CS (1991) Peirce on signs: writings on semiotic. UNC Press Books, Chapel Hill
Rettberg JW (2014) Seeing ourselves through technology: how we use selfies, blog and wearable devices to see and shape ourselves. Palgrave Macmillan, New York
Rich E, Miah A (2009) Prosthetic surveillance: the medical governance of health bodies in cyberspace. Surveill Soc 6(2):163–177
Rose N (2000) Government and control. Brit J Criminol 40:321–339
Schrape N (2014) Gamification and governmentality. In: Fuchs M, Fizek S, Ruffino P, Schrape N (eds) Rethinking gamification. Meson Press by Hybrid Publishing Lab, Lüneburg, pp 21–46
Sfez L (1995) La santé parfaite: critique d'une nouvelle utopie. Éditions du Seuil, Paris
Shulz W (2004) Reconstructing mediatization as an analytical concept. Eur J Commun 19(1):87–101
Smith GJD, Vonthethoff B (2016) Health by numbers? Exploring the practice and experience of datafied health. Health Sociol Rev 26(1):6–21
Sodré M (2002) Antropológica do espelho: por uma teoria da comunicação linear e em rede. Vozes, Petrópolis
Swan M (2009) Emerging patient-driven health care models: an examination of health social networks, consumer personalized medicine and quantified self-tracking. Int J Environ Res Public Health 6(2):492–525
Swan M (2013) The quantified self: fundamental disruption in big data science and biological discovery. J Big Data 1(2):85–99
Van Diest M, Stegenga J, Wörtche HJ, et al (2015) Quantifying postural control during exergaming using multivariate whole-body movement data: a self-organizing maps approach. PLoS One 10:0–17. doi: 10.1371/journal.pone.0134350
Van Dijck J (2014) Datafication, dataism and dataveillance: big data between scientific paradigm and ideology. Surveill Soc 12(2):197–208
Véron E (2014) Mediatization theory: a semio-anthropological perspective. In: Lundby K (ed) Mediatization of communication. De Gruyter, Berlin/Boston
Whitson JR (2013) Gaming the quantified self. Surveill Soc 11(1/2):163–176
Whitson JR (2014) Foucault's fitbit: governance and gamification. The gameful world — approaches, issues, applications
Zichermann G, Cunningham C (2011) Gamification by design: implementing game mechanics in web and mobile apps. In: Gamification by design: Implementing game mechanics in web and mobile apps. O'Reilly Media, Inc, p 208

Igor Sacramento has a PhD in communication and culture from the Federal University of Rio de Janeiro (UFRJ). He is a full researcher at the Communication and Health Laboratory at the Oswaldo Cruz Foundation (Laces/Fiocruz). His research interests are multidisciplinary, incorporating communication, cultural studies and history. He is an author and editor of over ten books. His recent researches and writings focus on the articulations between media culture and discourses on health, illness and the body in contemporary society. PhD in Communication and Culture at Federal University of Rio de Janeiro and Full Researcher in Communication and Health at Oswaldo Cruz Foundation, Brazil.

Vanissa Wanick holds an MBA in marketing from the University Federal Fluminense (UFF) and a BA in design at PUC-Rio. Currently, she is a PhD researcher at the University of Southampton (Winchester School of Art), looking at advergames across cultures. Her research interests are cross-cultural HCI and persuasive design, gamification, games for behaviour change and sustainability. PhD researcher at University of Southampton, Winchester School of Art, UK.

Chapter 4
Can Quantified Self Be a Facilitating Technology to Help Older Adults Stay Longer in Their Home?

Christel De Maeyer

Abstract Readers of this chapter are taken through a journey by the author, who narrates a real-life story of a lady called Maria who is 75-year old and lives with her husband Albert, 81-years. The narration describes the lives of Maria and Albert, detailing their enjoyment of physical activity, and their children. Yet, one-day Maria is diagnosed with Alzheimer's and through the narration the author describes the experience that Maria and her family experience. Fast forwarding, to the year 2030, the author continues her narration describing how technology may fit into Maria's life and that of her family; including the use of wearable devices and sensors integrated into the home where Maria lives, and enabling her family to track in real-time Maria's sleep patterns and overall health. Additionally, this chapter discusses the fields of ageing in place, the quantified self (QS), and based on existing work in this field, the author explores a taxonomy for the QS, referencing and drawing on the work of Deborah Lupton. Further exploration and discussion in the areas of appropriation, affordance, rights, and risks of QS are provided with the author exploring how digital technologies fit within the healthcare system.

4.1 Introduction

In a society where we are confronted with an aging population, resulting in rising healthcare costs as a consequence of chronic health conditions (European Commission EGECFIN 2012), the concept of prevention is becoming an important area of research and development, for governments and industry. Across public health organizations and academia, researchers are exploring solutions in a bid to keep older adults at home longer which is a priority in the healthcare discourse (UNFPA 2011).

C. De Maeyer (✉)
Department Graphical Digital Media, Artevelde University College Ghent, Ghent, Belgium

Department of Industrial Design, Eindhoven University of Technology, Eindhoven, The Netherlands
e-mail: C.a.a.D.maeyer@tue.nl

H.R. Marston et al. (eds.), *Mobile e-Health*, Human–Computer Interaction Series,
DOI 10.1007/978-3-319-60672-9_4

In 2014, across Europe, the number of adults aged 65+ years was 19%, there is an expectation that there will be a rise toward 23.5% in 2030 (Eurostat 2014), and the number of adults aged 80+ years will double to 6.4% in 2030 resulting in increased frailty. Frailty is described by Fried (2001, p. M146), as a "geriatric condition and is a collection of symptoms where there is a decrease of reserve and resistance to stressors." Additionally, frailty is a commonality across aging cohorts, which in turn may result in suffering from (chronic) health conditions and refers to different components such as "the mental and physical state of the elderly and the social environment. The accumulation of these components, makes the frail elderly vulnerable (Van Kan 2008, p. 31)." Previously, frailty was primarily associated with biomedical and the physical state. However, more recently, research argues that the psychology and social components of the frail elderly are also important elements which should be considered (Rolfson 2006). The Tilburg Frailty Indicators identify four components which include "cognition, symptoms of depression, anxiety and coping," (Gobbens 2010, p. 345) while the social components comprise of "living alone, the social relations of the older adult and social support that is provided (Gobbens 2010, p. 345)."

This evolution brings a new way of thinking, coupled with several challenges, barriers, and enablers. One of the challenges is to establish a form of affordable "dignified aging." Waiting lists at care centers/residential homes are long, which for some older adults, their carer's, support networks and family to provide the notion of staying at home longer resulting in the concept of "aging in place." Moreover, on the one hand, more support in home care and a socialization of care is required and needs to be available, while caregivers, family, and friends will need to take a bigger responsibility in taking care of their aging relative/friend, to establish "aging in place" in a comfortable matter.

To tackle these problems, technology and its attributes have become popular in a bid to support the more vulnerable and frail older adults in conjunction with the physical environment and are becoming more prevalent (Tacken 2005; Altus 2000). Over the last 15 years (2002–2017), multi- and cross-disciplinary research has been conducted by scholars in relation to assistive living (smart homes) (Mynatt 2000; Klack 2011; Birnholtz 2010; Himmel 2016). Yet, today's evolution in technology proposes more personal, tangible, and cheaper solutions that open new possibilities toward the elderly.

A relatively new trend is the Quantified Self (QS) which is based upon the recording and measuring of one's daily activities. This can include walking or other sport-related activities, sleep patterns, and/or heart rate, tracked by hardware devices such as a Fitbit or Jawbone (n.b. different models measure different elements). Wearable technology such as Fitbit, Jawbone, or similar devices with suitable and relevant software/applications could be an approach that can facilitate more independence for the older adult and offering peace of mind for family members and/or friends who culminate in being their support and care network(s).

As one ages, children and grandchildren move away for employment which can result in being at home alone, having little contact with friends, family, neighbors, and/or community groups (e.g., church, social activities). Living alone can be a worry for the children, friends, or extended family members who care for them. Unintentional falls resulting from hazards in the home (e.g., rugs) and medication

(Gschwind et al. 2014, 2015) are a worry, as they may occur more frequently due to a variety of causes, and may result in severe injuries or death. Prevention and detection of falls are important, if we want to establish an "aging in place."

A recent study – the iStoppFalls (2011–2014) – explored the use and deployment of technological solutions in conjunction with strength and balance exercises adapted from the Otago exercise program (Campbell and Robertson 2003). The iStoppFalls project designed and developed purpose-built software, integrating three purpose-built exergames incorporating strength and balance exercises from the Otago exercise program, in conjunction with adapted fall risk assessments (Gschwind et al. 2014, 2015), (Marston 2015), educational material, and a social media platform to motivate participants to engage and share their experiences of the iStoppFalls platform. The conclusion of the iStoppFalls project showed that the ICT exercise program is feasible in a home environment of older community-dwelling people without supervision; there were no adverse events or falls during the intervention which shows it was safe for older adults. An initial instructor support is needed to initiate the exercise program; the program overall was perceived as enjoyable and acceptable to use. However, more work is needed to be done on the level of adherence of the program to create routines in people's life. Participants who exercised for more than 90 min a week showed a reduced physiological fall risk, in comparison with the control group (Gschwind et al. 2015).

While researchers have proposed several fall detection technologies in the form of sensor floor systems, which can be integrated into the home environment (Klack 2011), accelerators monitor gait (Salomon 2010), (Brauner 2014), (Geraedts 2014), (Geraerdts 2017) and wearable sensors (Mann 1997; Patel 2012; Jovanov 2011).

In this chapter, we would like to focus on wearable technology, including wearable devices and sensor-based technology, which have become more affordable for larger populations. These wearable technologies can collect a lot of information about the user, such as physical activity, sleep patterns, location, heart rate, and calorie burning, to name a few; this gathered data can then be sent to family, support networks, and/or health practitioners.

In addition, these wearable technologies are more commoditized today and a more robust alternative than early prototypes, such as "Diarist" (Metaxas 2007); a "Daily Activities Diarist," reporting on daily activities through a wireless sensor network in the home of the older adult that gathers all the data and presents an "Activity-of-Daily-Life journal"; and "Arurama," (Dadlani 2010) a sensor-based system that provides peace of mind and a sense of connection with the supported network of the older adult. Arurama collects data about presence in the home, sleeping patterns, and weight through an unobtrusive ambient informative system.

Today, these wearable devices or sensor-based systems are not completely suitable for the frail older adult; the software that is accompanied with these devices requires users to be digital literate. For many wearable devices, such as the Fitbit or similar, when a device is purchased, there is no instruction manual, which for many people would be a problem. Setup requires the device to be activated through registration on the Internet which means the user of the wearable devices/technologies needs to either have access or own a computer/laptop. Although for younger people, who may have grown up with this type of technology and devices, their digital literacy will be higher than older adults. Additionally, the in-built software on

wearable devices is not set up to monitor and sends and receives information to those who may need it (i.e., family, support networks, and/or health practitioners).

In this chapter, we propose a narrative approach toward design research, based on a real story by positioning the current situation toward a future model and what the role could be of technology in facilitating and enhancing "aging in place" with early signs or symptoms of Alzheimer patients. Symptoms such as lost in time or place, memory loss, problems arising from planning daily task, and other related problems occur with early-onset Alzheimer's disease. We explore how can we let technology flourish which will mediate the daily lives of frail older adults in an "aging in place" future?

Narrative Story: Illustrating Maria's Path as an Alzheimer Patient

Maria is a 75-year-old woman who lives with her husband (Albert) who is 81 years old. Throughout their lives, they have been active, cycling, walking, swimming, camping with their young family many decades ago, and enjoying holidays home and abroad for long periods at a time. Maria enjoys swimming three times a week; she socializes with her friends in town, having lunch and coffee, and takes daily walks. However, one morning Maria's daughter (Helena) is visiting and Albert updates Helena on her mother's activities, which include her wondering around the house at night. This comes to a climax, where Maria tells Helena that she thought she was dead or dying. This is an episode of a psychosis and is diagnosed by Maria's doctor, who is hospitalized for a few weeks to undertake an observation. For Helena and Albert, the accumulation of these events was the onset of early Alzheimer diagnosis for Maria.

From that moment onward the diagnosis of Maria's Alzheimer's disease, Albert, Helena, and the rest of family's lives were going to change. Through assistance and communication with health practitioners, a weekly nurse now attends Maria and Albert's home, to place the medication into Maria's medication box. Over some years, this home goes well; the medication that Maria is prescribed is working well and postpones the severe phase of Alzheimer's disease. Helena has siblings, and among them, they cook up for their parents and all seems to be going well.

However, after some years, daily life seemed to change for Maria, she is eating less, and there seems to be a general decline in domestic tasks. Maria is still vulnerable around the house at night, and her condition seems to have decreased. Maria's episodes of memory loss and/or experiencing memories from early age/childhood are becoming more frequent. From Helena's standpoint, she is concerned that her mother is becoming frailer and the inevitable fall and the complete loss of senses, resulted in Maria being hospitalized. Further health issues arise from this, where Maria is losing a lot of weight and is dehydrated. For Helena, her siblings, and Albert, Maria is transitioning into the last phase of her life, which is spent in a closed institution for Alzheimer patients where she has a revival for a few months, but then slowly goes into

her own world and eventually dies 2 years later. During Maria's stay at the retirement home, her daily routines are well planned and organized. Maria wakes up in the morning, is given breakfast, and is washed daily. Once or twice a week, Maria goes into a relaxation bath, a soft jacuzzi bath, with calming music, creating a comfort and cozy atmosphere, which she enjoys a lot. The staff and other residents are entertained through different activities as much as possible and helping with little domestic things in the retirement home. In Maria's bedroom, she has a lot of personal items such as photographs of children and grandchildren, and a smaller replicate of the home is created to experience the feeling of the ancestral home. Additionally, experiments are conducted with "activity aprons" (see Fig. 4.1); activity aprons stimulate sensory activity with patients with Alzheimer's disease. They have different assets sowed on the apron, such as little pockets with a zipper, a pocket that makes a bit of sound, and little plush animals to play with, all to engage the minds and fingers with Alzheimer patients.

The siblings visit as often as possible and take little walks with Maria. They take her out to have Maria's favorite ice cream which is vanilla ice cream with hot chocolate sauce. However, in time, it doesn't become easier, Maria has been in the home for 1 year, a lot of patience is needed by those attending to Maria during meal times, and over time, Maria declines, slipping into her own world and slowly disappears.

Fig. 4.1 Activity apron (Permission granted by C. De Maeyer)

Reflecting on this narrative, and possible scenario of aging adults, one can think about how we can integrate digital technologies such as wearable technologies, mobile apps, or assisted living technologies to help Maria stay longer at home or facilitate "aging in place," giving support in the daily follow-up of Maria's physical, psychological, and social state of well-being, as a preventive and alert system for behavior change that occurs in the process of Alzheimer patients. Furthermore, looking at the challenges that bring these digital technologies, mainly in the area of ease of use, privacy, and the control or ownership of the data which is collected by the respective digital technologies, there needs to be an established informed consent with all interested parties, the support network, the person(s) who are involved in following up Maria's Alzheimer's disease, and the social acceptance of these digital technologies.

It's 2030: How Does Technology Fit in the Life of Maria and Her Family?

Maria is living an active life and is living in a connected smart home environment. With the advancement of technology, her connected home has multiple sensors which can wake her up in the morning and provide her with a daily weather report and her daily routines. Maria prepares for her day; she showers and receives information on her shower time and water usage. Her walk keeper application suggests to her that while it is dry outside, she should consider going for a walk, while her grocery delivery will be arriving later that afternoon. The grocery list is based on a series of sensors connected to her fridge; through her bank details and via her wearable implant, she could process and agree to purchasing her latest groceries. Her implant acts as a heart rate monitor and blood/glucose monitor; her daily/weekly physical activity comprises of walking, swimming, gardening, cycling, and socializing with friends over a coffee. Maria is excited because every week she receives new recipes; these recipes are good reminders to prepare healthy food on a regular basis, considering Maria's diet. Maria slides through the different recipes that have been delivered and she chooses to add some ingredients to her shopping list, so she can cook some of the new recipes that she has saved.

Based on the data from her wearable implant and the sensors connected throughout her home, Maria can access real-time data based on her sleep and overall health monitoring. Maria notices that her sleep patterns have changed over the last few weeks; also her light report tells her that she woke up several times at night and that she had little walks around the house which she cannot remember. Based on this recent information, Maria makes the choice based on the information that she has received, her doctor, and her connected home to the next level. She chooses to integrate a social companion (robot) to accompany her all the time; the companion learns Maria's daily habits and

can anticipate incidents or anomalies. Maria's social companion is called Robert.

Maria and Robert relationship grows over time based on the essence that Robert is always there, and when time passes, he gets to know Maria better. He anticipates her moods, helps Maria with taking her medication on time and the correct dosage, reminds and motivates her to do her daily exercises, and provides access to cognitive games and stimuli which challenge Maria. Robert is Bluetooth enabled and collects all of Maria's data such as bio state, physical state, and mental state. Robert tracks the number of steps Maria has walked, her sleep pattern, her daily food intake, and her fuel usage because these items are connected to Robert which is the main server and data gathering social robot. Robert is connected to the outside world, which includes the caregiver who passes by on a regular basis to check in on Maria, her friends and family members, and the support networks. Additionally, Robert is connected to the hospital where Maria is in treatment for her early Alzheimer symptoms and is also connected to the insurance company which manages Maria's health insurance.

On a fresh Spring day, Maria falls and has a severe heart attack. Robert has recognized how severe this is and is negotiating with all the data he has, in addition to informing the health insurance company and the hospital and processing Maria's will which will (if necessary) be delivered to the necessary people and departments (e.g., the solicitor). Will Robert decide to send an alert to the necessary institutions for urgent help or let Maria go and let her die in the comfort of her smart home considering her wishes to not reanimate her and do everything to let her die surrounded by her friends and family and her doctor?

This scenario is brought forward to think more in depth on how we can use future technology within healthcare and to consider what future research is needed to secure a broader adoption. We find similar scenarios in a different context in a study focusing on ambient intelligence (Ducatel 2001), where a projection is done to the year 2010. The proposed four scenarios set in different contexts, but equally important, were in the area of mobility – Road Warrior, Digital Me, traffic, sustainability and commerce, and social learning. If we compare the scenarios with the one that is proposed here toward the year 2030, one will notice that the results showed in the study are still very relevant and a continuous topic for research. First, it has to be seen as "progress and positive force for society and political development." Second, it has already "open lots of new opportunities for businesses and firms" specialized in the respective domains, in our scenario, the healthcare sector. Third, the "socio-political gains or pains" require more in-depth studies (Ducatel 2001, p.8).

4.2 Aging in Place: What Preceded

Previous work has shown that older adults have a positive attitude toward new technologies (Demiris 2008), this will be more so with the Generation X and the Millennial generation who have grown up having technology in their lives, acting as more than a device for work-related reasons.

Previously, with technology use and access comes possible barriers and enablers that require further analysis and understanding. As our society moves toward a socialization of care, there is a shift toward a more collaborative model between the older adult, family, friends, caregivers, and extra support networks, which are demanding also more responsibility. Furthermore, there is also a need and demand of more self-management and the ability of adaptation with the older adult in their daily life. One of the central questions that needs to be considered and asked is: who does take or will take the responsibility for this provision, and for those individuals who agree to be part of this, how involved will they be to undertake and execute this new responsibility? According to Coventry (2014), there are three main factors in engaging patient self-management. Do patients have the "knowledge and emotional and physical capacity" to engage in self-management? Is there enough "motivation" with the older adult, and how will the "responsibility" be taken in the supported network? Who will be responsible for the several tasks and/or labor within a self-management environment? In addition, one needs to consider also the "trust and confidence" we give in digital technologies to help us in self-management. A positive scenario like the narrative of Maria can turn into a negative, dark scenario. Possible threats and barriers one needs to consider are the digital divide, trust, privacy, security and identity (Punie 2005).

Privacy is one of the returning issues, also in "awareness systems" and/or "monitoring systems" as known in "smart homes" (Birnholtz 2010; Brittain et al. 2010; Markopoulos 2009). Awareness systems enable us to be aware of certain aspects in the smart home, because it is "Related to social awareness, such as is the presence of someone at a fixed location to the awareness of someone's daily life activities" (Markopoulos 2009, p. 70). Smart homes are homes that are equipped with technology in the form of cameras and sensors, to enhance the safety of the patient or older adult and to monitor their overall health condition. For example, a smart thermostat (e.g., Nest) that regulates the heat in the home based on your daily habits and routines in the home can provide the user with a daily schedule for heating the house, also providing the outdoor temperature to regulate your home temperature. Additional examples are smart lights (e.g., Hue) that can be remotely controlled and adjusted to moods, pressure sensor-based tiles which can sense when a person falls, and motion cameras to locate movement in the smart home, a display that provides homeowners about all the information from the connected devices and simultaneously is used for entertainment purposes.

Further elements that can extend the smart home and provide additional information to the homeowners include smart mirrors that can display messages; this could

be useful as a reminder to people who take medication and other daily activities or appointments that are scheduled for the forthcoming week(s). A smart bathroom can include a water regulating temperature system that controls the temperature of the water and a sensor flushing system for the toilet. These systems which incorporate sensors and cameras are integrated into the home and experienced as an "invasion of privacy" or "a threat at one's dignity in one's own home" (Machiko 2010, p. 146). This is especially the case with video cameras. For example, the installation of the video camera in more public spaces like the living room versus the bedroom and bathroom will have lower or higher acceptance (Himmel 2016). With older adults, "their perceptions of the potential of the technologies is focused on a reactive role (detecting emergencies) rather than a proactive one (monitoring a situation to detect trends or predict issues or concerns)" (Demiris 2008, p.123).

Even though in house monitoring through smart home technology can provide peace of mind and the feeling that a crisis can be controlled quite quickly, which in turn enables the possibility of remote follow-up, it seems a positive approach and concept. Remote follow-up can be conducted through communication between the older adult, caregivers, family, and friends, to reduce the feeling of isolation, loneliness, and solitude with the older adult (Birnholtz 2010). Technology such as Skype is one solution, to mediate interaction with family and the older adult (Demiris 2008). Social media such as Facebook also provides users with several opportunities to engage with loved ones and possibly reduce isolation through sharing content (e.g., photographs), using the chat function, or making a video call like Skype. The use of video monitoring technology with older adults can have multiple purposes, from monitoring the different rooms within a home or as a communication means to communicate with the outside world. The acceptance of this technology will differ within different target audiences, for example, older adults with mobility problems or older adults with hearing problems, and will have different needs and requirements. Other restraints are the positioning of the monitor devices, in rooms, and whether there is facial recognition or not (Leonardi 2009; Arning 2015). Research shows that Ambient Assisted Living (AAL) technology acceptance is low; in the case of monitoring, it gives a feeling of being "watched over" and is experienced as an "invasion of privacy" (Himmel 2016).

The proposed digital technologies are not cheap and require adjustments to the home of the older adult(s) and its environment where they are installed (Machiko 2010). Alternatives such as the emergence of wearable technology might become new norms toward new lifestyles in general and could also be appropriated for older adults in securing aging in place. In some instances, these technologies are used by early adopters who are digital literate, by participants in studies (e.g., MK Smart project, UK), and by individuals who are searching for more economical solutions in monitoring their home in regard to fuel consumption or who are interested in data such as those in the quantified self-movement. In the following sections, we will take a closer look at the current use and taxonomy of Quantified Self and what role it can play in helping the older adult in aging at place.

4.3 Appropriation and Affordance of Quantified Self

Quantified Self is a relatively new domain; it was pinpointed by Gary Wolf and Kevin Kelly in 2007, where they stated that Quantified Self is "tracking every facet of your life" (Wolf 2009). Indeed, the Quantified Self movement was started in 2008 whereby people come together to talk about their experiences in quantifying themselves through technologies such as the London Quantified Self meet-up (https://www.meetup.com/LondonQS/). In a sense this is not new, people have always been quantifying themselves (e.g., how many movies you see in a year, how many books you read, keeping finances in excel, or how many calories are consumed). However, with technological advancements, it has enabled individuals to take this a step further. Today we collect information about how many steps we take during the day, how many hours a day we sleep, how many calories we burn, menstrual cycles, spending and purchases, and reproduction/pregnancy recording. Most Quantified Self applications are aimed at behavior change and preventive healthcare (Quantified Self London Meetup 2014; The Economist 2012).

Exploring the current use of self-tracking and its origins, it is noticeable that within the Quantified Self movement today, it is used by people with a specific profile, such as software engineers, startup founders, and data analyzers, measuring mainly physical activity, food, weight, sleep, and mood, who are going through different phases in their self-tracking activity. Outside the Quantified Self movement, in a recent report published by Pew Internet Research, 69% of adults reported to track their health (n = 3014), while 21% of those US individuals identified in using some form of technology to track their health and analyze their data (Fox 2013).

Previously, Quantified Self users experience different phases in their self-tracking. Epstein (2015) proposed a model for lived informatics for personal informatics, comprising of three stages, initially starting with the decision to track and decide on the selection of tools to track. Choosing or deciding to track oneself could be for many reasons and include to improve one's health, to improve lifestyle, or to find a new life experience/activity (Choe 2014). In the selection of tools, there is a compare process to select the appropriate tool; one could choose to use mobile apps such as Runkeeper (running mobile application) or Human (a physical and calorie tracker) or decide to wear a wristband such as Fitbit or Jawbone to name a few options.

Stage two relates to the "tracking and acting" process which is "an ongoing process of collecting, integrating and reflecting" (Epstein 2015). Choe (2014) notes three activities, "collecting, integrating, and reflecting," which are distinct and dependent upon data. Self-trackers learn about their behavior during the process of collecting and monitoring the data, "the main importance however, is to get meaningful insights and reflect on data to make positive change" (Choe 2014, p. 10).

Stage three relates to the "lapsing stage," which is associated with individuals/users who choose to stop self-tracking for a set amount of time or completely. Based upon recent research, the dropout rate is quite high for several reasons, including technology failure, lack of interest, curiosity which is gone, or the cost of tracking

in terms of time (Endeavour Partners 2014; Fritz 2014; Karapanos 2015; Shih 2015; Epstein 2016). Finally, there is "the resuming phase"; these can be short breaks, where self-trackers have gone on holiday and forgotten to take their wearable device or they choose to have a longer break. In the latter, the self-tracker might start again by reflecting first on the older data and then decides later to start tracking again and collecting more data depending on the tracking activity (Epstein 2015). As the self-tracking devices aimed at the older adult, they will be transferring information to the supported network and not necessarily to the older adult; these stages will have less relevance, although they will still be there. The evaluation of the self-tracking activity has a different aim, mainly following up the daily activities of the older adult, and will not have the aim to change behavior in that sense but more steering and follow-up of the daily routines and habits of the older adult.

As Quantified Self diffuses in different domains, it has the potential to be integrated into the lives of our current and future aging populations to assist their "aging in place." For example, with the increase of longevity, coupled with chronic health-related impairments, and an increase of social isolation, it is possible the use and deployment of wearable devices could have a place in the context of "aging in place." In the domain of frail older adults, wearable devices and connected health technologies integrated with smart homes have the potential to become a surveillance tool (detecting emergencies) rather than a (health) behavior change tool (proactive use to see trends); it will be a tool or solution to "watch over" people's daily lives and detecting anomalies and a follow-up and reminder system as we have seen in the narrative of Maria, e.g., reminder for medication, daily walks, eating healthy food, getting in touch with family and friends, and follow-up on sleeping patterns, eating habits, walks, and daily routines in general. In the following section, we will discuss the sociocultural aspect of it and will explore and examine the work of Lupton who has undertaken a vast array of research in "self-tracking cultures" followed by an overview of the different affordance and appropriation of these digital technologies.

4.4 Taxonomy to Categorize Quantified Self

Quantified Self is gaining a lot of interest from the academic communities by researchers in computer science, human computer interaction, rehabilitation, and health and well-being. This cross- and multidisciplinary work is crucial for the adoption, and usability, of these new devices in addition to understanding the health benefits (positive and negative) to using this type of technology. The work of Lupton (2014) takes a multi- and cross-disciplinary approach; an authority in this domain through her research of sociopolitical and culture impact is equally important for adoption process to diffuse in other domains, "The practices, meanings, discourses and technologies associated with self-tracking are inherently and inevitably the product of a broader social, cultural and political process (Lupton 2016, p. 1)."

Given the rapid expansion of technology since the turn of the twenty-first century and in particular the wearable technology market, governments and corporate

entities alike have become interested in this field. Quantified Self is moving from personal or individual use toward other domains such as healthcare, commercial profiling (building profiles based on our online behavior together with other data that we collect and share in the cloud), and insurance application (certain wristbands get promoted by insurance companies and have the ability to access our data; in that sense the insurance will be personalized based on your behavior) (Olson 2014). Categorizing these different modes in Quantified Self enables us to think more clearly about the application in certain self-tracking activities and how they are appropriated and in which domain.

Lupton (2014) suggests there are five modes of self-tracking:

1. Private
2. Communal
3. Pushed
4. Imposed
5. Exploited

While these modes can interconnect, or overlap with one another, for this chapter, we have limited our focus primarily to private self-tracking, and pushed self-tracking, in addition to exploring the area of communal self-tracking. The limited focus of these three modes in this chapter connects to the purpose of self-tracking applied to older adults. Depending on the state of the older adult, the private self-tracking will or might be a voluntary activity undertaken by the older adult. In further states of older adults or frail older adults, the pushed self-tracking might be pushed by friends, family, or the supported network. The communal mode of self-tracking applies to both modes (private and pushed) as older adults will share their data with their supported network to give that sense of peace of mind.

The definition of these five modes has been outlined by Lupton (2014) which are as follows:

The first mode "private tracking" is a mode widely practiced with in the movement whereby the users collect data about themselves. These types of users may share their data in specific communities or on social media platforms, as suggested in the "communal mode" of self-tracking:

> Private self-tracking, as espoused in the Quantified Self's goal of 'self-knowledge through numbers', is undertaken for purely personal reasons and the data are kept private or shared only with limited and selected others (Lupton 2014, p. 6).

With private tracking, this can be associated with older adults who wish to stay at home longer but can be reassured that their family can observe their activity levels. In addition, as mentioned, the private self-tracking can be an activity that older adults take on themselves, as a sort of self-surveillance on different aspects of their daily life or to continue being engaged in several activities they practice or are organized by the community.

The second mode, "communal," is based on the notion of sharing data with others, be it friends, family, and strangers (e.g., meet-ups). They are not necessarily sharing on social media, but they have other means of sharing within a closed community.

> While communal self-tracking, in its very name and focus on the 'self' may appear to be an individualistic practice, many self-trackers view themselves as part of a community of trackers (Boesel 2013a; Lupton 2013a; Nafus and Sherman 2014; Rooksby et al. 2014). They use social media, platforms designed for comparing and sharing personal data and sites such as the Quantified Self website to engage with and learn from other self-trackers (Lupton 2014, p. 8).

The third mode as noted by Lupton (2014) is "pushed self-tracking," which might be related to the stimulus of others, such as peers, who benefit from self-tracking and stimulating others to start a self-tracking activity, or other actors stimulating or promoting self-tracking. For example, a dietitian may suggest to patients that they should consider tracking their food intake to ascertain the influences of the issues in question.

> Pushed self-tracking departs from the private self-tracking mode in that the initial incentive for engaging in self-tracking comes from another actor or agency. Self-monitoring may be taken up voluntarily, but in response to external encouragement or advocating rather than as a wholly self-generated and private initiative (Lupton 2014, p. 7).

From an "aging in place" perspective, the "pushed self-tracking" mode could be suitable for an older adult or elderly person because they could be "pushed" into this mode by a caregiver, family member, or a friend. In the first narrative of Maria, it would have been helpful to use Quantified Self tools in the follow-up process when Maria got her first psychosis that led toward the diagnosis of early Alzheimer's disease. As Maria needed more help to continue her daily routines, habits, and domestic tasks, caregivers will only report something when there is something out of the ordinary or unusual behavior which has been observed of the older adult and that might only be through the weekly visits during that period of early Alzheimer's disease.

Taking a reflecting approach on the work by Lupton, further considerations need to be considered for future implications. There will be a general trend toward a neoliberal model toward "self-care and homo economicus," from being a "partner of exchange" to being an "entrepreneur of himself," and a proactive prevention society, including a reorganization of health insurances and government policies. From the standpoint of bracelets or wristbands, the aim is to give a safer feeling, more independence, and autonomy to the older adult, to create a peace of mind with the children, family members, and friends. There are different aspects to look at from an older person's perspective. The aim of these wristbands is very different; their focus is more on surveillance technology than proactive measuring physical activity, sleep, heart rate, and dietary intake. Therefore, this information is more important to the person who is monitoring their loved one.

4.5 Appropriation and Affordance of Quantified Self for "Aging in Place"

The model of appropriation for "aging in place" is different in Quantified Self tools for the older adults. Aging in place enables the older adult to remain longer in their home and live more independent and autonomous as opposed to living in residential

care institutions (Davey 2004). However, the Quantified Self tools that are specifically built for older adults have different function, for example, Zembro (http://www.zembro.eu) is a wristband or watch that monitors the whereabouts of a user and has an alarm that warns the support network of the older adult when something goes wrong. Other example, the Allen Band (http://theallenband.com/the-allen-band-idea/), is a wristband device which monitors heart rate, in conjunction with movements via a global positioning system (GPS), body temperature, and any sudden movements such as falls. It is connected and synchronized to a cloud service where the caregiver can consult or receives alerts from the system when emergencies occur. The older adult's physical activity and location are monitored by using wearable technologies; the data collection is transferred to the professionals, caregivers, family, and friends. The software visualizes trends and anomalies to provide information on the health and condition of the individual. In most applications, the older adult doesn't see the data that is collected by them, even though older adults would be interested in their data. Older people are commonly assigned to the role of object rather than subject in the development of technology (Brittain et al. 2010, p. 273).

Furthermore, the wristband is not discrete and might have a stigmatizing effect to the older adult who is wearing it; it also has an impact on their self-esteem or self-image. We could compare it to hearing aids, which are more in the closet and then behind the ear. This is mostly about vanity but also not publicly admitting one may have a hearing problem (Allen 2017). Making the wristbands or bracelets more fashionable will help in not stigmatizing the older adult but make them nice to wear.

4.6 The Rights and Risks of Quantified Self Technologies

The attitude of future aging populations may be more positive to use wearable/digital devices and could be more common and popular than at present. For some younger people, they may be more inclined to deploy wearable devices on their older parents or relatives who have been diagnosed with Alzheimer's disease to maintain their surveillance to ensure their parent(s) are coping. Yet, this surveillance may "constrain the choices of older people and undermine their decisions to take risks" (Brittain et al. 2010, p. 273; see also Percival 2006). It is argued that (Ballinger 2002, p. 305) "while service providers are oriented to the management of physical risk, older people themselves are more concerned with the risk to their personal and social identities. The challenge of the self-image." The frail older adult is avoiding the stigma of being frail and vulnerable. In addition, the supporting technologies can intervene in the daily habits and routines of the older adult, in so much as reinforcing the emotion of an institutionalized home (Exleya 2007).

Moreover, these wearable devices are designed and developed by private companies and by default also collect a lot of data about the users. The ownership of the data should lie with the user; in the case of Alzheimer patients, this is a responsibility for the family or trusted guardians/friends to have the ownership and informed consent for what reasons the data could be used and how it would be used. One can

think of different insurance models (rising in cost) for Alzheimer patients based on the data that is gathered by the Alzheimer patient. The personal private sphere or personal freedom might be in danger if this is not regulated well.

4.7 Social Inclusion and Human Contact

As these solutions require engagement and interactions from family members, friends, and caregivers who are possibly connected to the mobile application to monitor their parent, friend, or service user, further considerations are needed from the standpoint of design and its applications. We need to consider whether this solution will bring more engagement and interaction with those concerned (close family members, friends, and caregivers) as we shift responsibility of care to the senior and their connected community? Will the older adult in question still have the same contact with their close environment?

It has been argued by that in telecare, these technologies cannot replace the human contact, as older adults look forward to seeing and communicating face-to-face conversation with their caregiver(s) or the more informal contacts with caregivers, family, and friends. Therefore, it should not replace the face-to-face contact (Percival 2006) but decrease social isolation and ensue monitoring is being undertaken of a loved one. Will the social well-being within the connected group and the aging cohorts improve because of the surveillance function toward the older adults/elderly person? As Quantified Self tools are used as a personal device or application, it might facilitate further closeness between the older adult and their family, friends, or caregivers. The Quantified Self movement is open to people across the life span, and it should be considered that this domain may have a role in fostering intergenerational relationships. Enhancing and fostering intergenerational relationships through self-tracking and monitoring of loved ones can be enhanced through discussion of activities and sharing experiences. Yet, it should not be looked at as a main surveillance tool but also as a fun experience looking at the activity of the older adult and the whole experience that it brings about.

4.8 Living with Simplicity: Design Models for Quantified Self Targeted to Older Frail Adults

As these digital technologies are being introduced to lay people who are not necessarily tech savvy or digital literate, technology and wearable devices need to be user friendly both in terms of hardware and software. If the technology fails, the dropout rate will be high. If we take the behavior model by Fogg (2009), it enables us to think more clearly about different behavior design aspects. Initially, we look at the ability; does the user have the sufficient ability to use the proposed wearable devices and its services that are offered with the devices, are there effective triggers, and is

there sufficient motivation to use the product or service? A combination of these elements needs to be integrated continuously for behavior change to occur. There is an ability factor comprising of six factors: time, money, physical effort, brain cycles, social deviance, and nonroutine. These factors can influence and play a role in technology adoption and behavior change. Expanding upon some of these factors, further considerations need to be undertaken in regard to restraints for older adults which in turn would provide older users the opportunity and ability to use these technologies:

- *Money*. To buy all this new technology, is the older adult capable to buy and install these new technologies, or will there be funding from the government to fund parts of these technologies, connected to health insurance?
- *Brain cycles*. Is the older user's level of digital literacy appropriate to understand the technology and its additional attributes and functionality? For example, regular updates, privacy, should the need for automation be considered?
- *Physical effort*. We should think about passive tracking as much as possible, in so much as the older adult does not need to intervene in the tracking process. With active self-tracking, we understand that a user is actively involved in the process. For example, with Foursquare/Swarm (https://www.swarmapp.com), a mobile application, the user gives in his or her location and is checking in at a certain location; this is an example of active tracking. Unlike Human (http://human.co), for example, it is a mobile application; it will track your activity without the user intervening; this is an example of passive tracking. Other examples are MyFitnessPal (https://www.myfitnesspal.com), where you actively put in your food intake.
- *Social deviance*. Will the technology be widely accepted by the community or will it stigmatize the older adult and alienate them from the community? For example, will it decrease their self-esteem and create an image of weakness, admitting they are frail while they are not ready to admit the frailty? (Exleya 2007)
- *Nonroutine*. For many older adults today, using technology is not part of their daily activity. However, it is possible as our younger generations grow old, so will the routine of accessing respective technologies or social media platforms.

Living in a world where technology plays a big role in everyday life, simplicity is a key requirement in the use of all these technologies. Norman (2010) explores this notion through product and service design; "people try to simplify the paths they take. They try to simplify their lives, preferring short routes to longer ones (Norman 2010, pp. 126–127)." This concept is one to consider when considering the design and development of new technologies aiming for broader adoption.

The ease of use is very important as previous research has demonstrated, relating to the acceptance of technology by older adults (Bickmore 2003; Himmel 2016; Smarr 2012). Previously, we have discussed the Quantified Self as means to assist the older adult in giving them the ability to stay longer at home – "aging in place." Ensuring that the older adult has independence, choice, and autonomy, this is particularly important for adults who are living alone and their children and grandchildren live in another part of the country or overseas. Considering these types of

technologies as enablers and facilitators to create a balance between human commitment and the help and assistance of Quantified Self tools may assist 'aging in place' still human, enabled and facilitated by technology and humans.

Throughout this chapter, we have discussed the different areas which are becoming popular areas of research while considering these new technologies are becoming introduced into the lives of older adults now but also in the future, with the notion of "aging in place" successfully. While all areas of society from government to community/local/national organizations to families, healthcare and service provision, education, and policy makers need to explore, identify, and evaluate the consequences that technology has and may have in the future on the healthcare system, would it become more sustainable, how would it be funded, and how would adults with low digital literacy gain confidence to learn and become skilled in learning new ways of information for successful aging in place?

4.9 How Do These Digital Technologies Fit into the Healthcare System as a Whole?

4.9.1 Technologies of the Self

As these technologies become more integrated into the lives of society, further exploration is needed to look at the social and political impact this may have on the daily lives, while we as users become completely responsible for our behavior. How does this change the role of the caregiver? How will this impact on the delivery of health services on a EU level through health insurance or the national health service (NHS) found in the UK, and how will this be measured? What could the possible consequences be?

In the sociological literature, Michel Foucault's describes "Technologies of the Self, which permit individuals to effect by their own means or with the help of others a certain number of operations on their own bodies and souls, thoughts, conduct, and way of being, so as to transform themselves in order to attain a certain state of happiness, purity, wisdom, perfection, or immortality" (Foucault 1988, p. 18). In further analysis, Foucault discusses three themes which were dominant in former times when the problems were similar but solutions and subjects were different. One of these subjects is a medical care model:

> A medical model was substituted for Plato's pedagogical model. The care of the self isn't another kind of pedagogy; it has to become permanent medical care. Permanent medical care is one of the central features of the care of the self. One must become the doctor of oneself. (Foucault 1988, p. 31)

Referring back to the area of Quantified Self, Quantified Self is a practice that leads to self-governance, self-management, and self-entrepreneur and fits in a neoliberal thought or idea. Citizens are responsible for themselves out of self-interest which is also in the interest of the state. Question we need to explore and ask is how

will this be managed and experienced in this increasingly digital society in which e-health in general becomes a commodity and various stakeholders from private and profit making enterprises form partnerships to provide a series of services. Citizens are handing over control and ownership of their personal data collected by the wearable devices and are at the disposal of private companies and the Internet empires (Andrejevic 2014). In addition, depending on the social-political climate of the country, the personal data might be used as a means of oppression or being exploited by marketers; the personal data can be turned back upon the user (Lupton 2016a, b).

4.10 Care and Control: Social Sorting?

Taking into account older adults using different technologies and devices, not only do users assess themselves but are also been assessed by their family and friends. Possible other agencies looking and "watching over" the users as well are the companies delivering these technologies and possibly the caregiver or the caregiving institution(s). However, what needs to be explored is who is benefitting from this surveillance and does it or would it create more trust between the user and family?

The dichotomy between forced surveillance and voluntary surveillance today is blurring (Harcourt 2015). As argued, "our digital lives begin to converge with a form of electronic monitoring that increasingly resembles correctional supervision" (Harcourt 2015, p. 20). Harcourt's comparison with the electronic ankle band and the Apple watch illustrates a whole other meaning, as he notes:

> Some of us are forced to wear electronic ankle bracelets, others lustfully strap Apple watches onto their wrists, but in both cases, all of our daily motions, activities, and whereabouts become easily accessible to those with rudimentary technology-that is, when we are not actively broadcasting our activity, heartbeats (Harcourt 2015, p. 20).

Therefore, do frail adults and especially people with Alzheimer's disease have the agency to avoid or to voluntarily put all the tracking devices off? And if they do, who takes that responsibility when something goes wrong during that period that they are caught off-guard? If in the future these digital technologies will be connected to our healthcare insurance, will the insurance company still cover and pay out for an incident, especially if the older adult is not wearing the digital technologies or has put them on off as in inactive?

Additionally, through surveillance, there is the social sorting, a classification to manage a population or persons, also with the possibility to influencing populations and individuals. Today this is easy and possible through all the data that is collected in our networked, connected society (Lyon 2009). Social sorting can be conducted through different aspects of personal data that has been collected, for example, the location, age, gender, behavior, and communication by mail or texting. Thus, a whole set of parameters that can then be applied for prediction, intervention, or the commercial purpose while also informing policy as local, regional, and national levels of government aimed toward new directives, new social settings, relations, and power that has been delivered through knowledge collected.

Therefore, we need to look at how this will impact on the public and private spheres of the individual/the user. Will the individual feel more free or independent and autonomous in this case? While exploring this notion of society from a global view, will this promote exclusion more than inclusion? Considering that not only there is the personal tracking through Quantified Self, but the larger body of surveillance means, social media platforms, online shopping behavior, and online administrative services, all the services we use in daily life can enable detailed profiling of a population.

4.11 Discussion

The goal of this chapter was to illustrate different research projects on smart technology, connected homes, and Quantified Self devices/tools. Our main research question if the Quantified Self can facilitate "aging in place" is a construct of complex and different aspects. Even though older adults have a positive attitude toward new technology (Demiris 2008) and see benefits in using new technologies, there are also barriers and enablers in using the technology across an older adult population.

The main barriers that were noted by (Pino 2015) were the lack of experience and the overall usability factors in new technology. Technology can have a lot of benefits for the older adult, but in order to achieve this uptake with our aging population, there needs to be greater attention for the design and development of these technologies (Patel 2012; Norman 1993; Norman 2010). As every person is unique, considerations should be taken for unique or individual customization and modular systems toward, and artificial intelligence could be the answer to fit and match user needs to the technology.

In our narrative story, Maria would have had a lot of benefits in having a stable companion, who is always there; reminds her about her daily routines and habits, in taking medication, to do her walks, to drink, and to eat; and even helps her with decision-making on a longer term. However, for Maria, living in a fully connected home asks for a different mind-set; one has to become used to the embodiment of technology in the fabric of one's everyday lives. In order to use Quantified Self in Maria's narrative, Maria needs to understand how to use these technologies; she has to be digital literate and have the capacity to control and shape her life and enhance her life with these technologies. The technology has to work flawless and has to be accurate, especially in healthcare as we will become more and more dependent on it in our lives to stay healthy and, in the case of older adults, to stay longer at home.

Furthermore, if one looks at the feedback loops of Quantified Self tools today, the feedbacks we receive from those technologies are very blunt and don't show any empathy at all "In light of feedback loops, people are approached as computer-like information processors, or "autocorrelating servomechanisms, a living part of a dataistic apparatus that allows the reflection and regulation of specific movements and behavior" (Ruckenstein 2015, p.10). They just report facts and figures. They will never ask the question "why have you not walked for a week" or even consider the context surrounding them.

Interconnectedness between devices and services will need to aggregate all the data that is gathered are an important asset in order to see correlations between the different data that is collected and for Maria to understand her digital self (Markopoulos 2016). As previously discussed, users need to be aware that all these devices are in the hands of private companies and that the data they gather is in the cloud somewhere, and as users, we need to claim that data and have ownership and the ability to decide what we as user can do with it. In the case of Alzheimer patients, this is the responsibility of the family, guardians, or trusted friends (Allen 2017; Lyon 2009; Harcourt 2015).

4.12 Conclusions

In this chapter, there has been a discussion focusing on the theoretical analysis based on existing literature from the fields of sociology and human computer interaction. More specifically we brought perspectives on user design aspects from a Quantified Self perspective. We look at different design frameworks that need to be considered in the design for older frail adults as the appropriation and affordance will be different. Future empirical research is needed to connect the theoretical models and to understand and learn more about how frail older adults and adults with Alzheimer's disease experience Quantified Self in their daily live in conjunction with respective support networks and friends.

Finally, this chapter has explored the privacy and surveillance relating to technology use, the main concerns that need to be considered as a default setting. The future of our aging populations is uncertain, yet, there are many technologies and digital devices available on the market and that have been researched; there is still a long way to go to make aging in place a smooth transition. Since the turn of the twenty-first century, society has seen many phenomenal hardware and software developments, yet, what will the next 10, 20, 30, or 50 years bring to the lives of people across different age cohorts/span? Will intergenerational relationships become stronger through learning new skills and to decrease isolation and social connectedness? What will replace communication tools such as Skype and social media platforms like Facebook? How will care be delivered in the homes of our elderly in the next 50 years? Will robots become part of the furniture like the hoover and the television set have become now?

Throughout the twentieth century, society witnessed many advancements through many contexts such as war. Yet the twenty-first century is uncertain from the perspective of politics and healthcare reform both nationally and internationally. What we can be sure of is the future is going to be exciting in the sense of ascertaining the feasibility of suitable technological devices for delivering healthcare and increasing physical activity and data tracking which will also inform on one's health and possible health insurance premiums.

Acknowledgments I would like to dedicate this chapter to my mom who died in 2016 with severe Alzheimer's disease. I used BodyMedia technology to monitor how she was sleeping and how much physical activity she was undertaking. Unfortunately, the latter was not working well, since she was not really making steps but more shuffled on her feet across the floor, and the system counted distinctive toe strikes to measure steps.

References

Allen A (2017) Will grandma want a robot seal? Retrieved from Politico: http://www.politico.com/agenda/story/2017/01/technology-healthcare-advances-for-the-elderly-000268

Altus DM (2000) Evaluating an electronic monitoring system for people who wander. J Alzheimer's Dis Other Dementia's 15:121–125

Andrejevic M (2014) The big data divide. Int J Commun 8:1673–1689

Arning KZ (2015) Get that camera out of my house!" Conjoint measurement of preferences for video-based healthcare monitoring systems in private and public places. ICOST 2015, pp 152–164

Ballinger CP (2002) The construction of the risk of falling among and by older people. Ageing Soc 22:305–324

Bickmore TW (2003) Relational agents: effecting change through human-computer relationships. PhD, Massachusetts Institute of Technology, program in media arts and sciences, School of Architecture and Planning, Boston

Birnholtz JM-R (2010) Independence and interaction: understanding seniors' privacy and awareness needs for aging in place. *CHI2010, Atlanta, GA, USA*. ACM, Atlanta

Brauner PZ (2014). Exergames for Elderly in Ambient Assisted Living Environments. International Conference on Pervasive Games – PERGAMES. Springer, Berlin/Heidelberg

Brittain K, Corner L, Robinson L, Bond J (2010) Ageing in place and technologies of place: the lived experience of people with dementia in changing social, physical and technological environments. *Sociology of Health & Illness* 32:272–287. https://doi.org/10.1111/j.1467-9566.2009.01203.

Campbell AJ, Robertson CM (2003) *Otago exercise program to prevent falls in older adults*. Otago Medical School, Otago

Choe EE (2014) Understanding quantified-Selfers' practices in collecting and exploring personal data. CHI 2014. ACM, Toronto

Coventry PA (2014) Capacity, responsibility, and motivation: a critical qualitative evaluation of patient and practitioner views about barriers to self-management in people with multimorbidity. BMC Health Services Research

Dadlani PS (2010) Aurama: caregiver awareness for living independently with an augmented picture frame display. AI & Soc 25(2):235–245

Davey JN (2004) Accommodation options for older people in Aotearoa/New Zealand. Institute for Research on Ageing/Business & Economic Research Ltd.

Demiris GH (2008) Senior residents' perceived need of and preferences for "smart home" sensor technologies. Int J Technol Assess Health Care 24(1):120–124

Demiris G, Oliver D (2008) Use of videophones for distant caregiving: an enriching experience for families and residents in long-term care. J Gerontol Nurs 34(7):50–55

Ducatel KB-C (2001) Scenarios For Ambient Intelligence In 2010. European Commission, user friendly information society. European Commission

Endeavour Partners (2014). Inside wearables. How the science of human behavior change offers the secret to long-term engagement. © 2014 Endeavour Partners LLC

Epstein DP (2015) A lived informatics model of personal informatics. UbiComp'15, September 07–11, 2015, Osaka, Japan. ACM, Osaka

Epstein (2016) Beyond abandonment to next steps: understanding and designing for life after personal informatics tool use. CHI'16, May 07–12, 2016, San Jose, CA, USA. ACM, San Jose

European Commission (EGECFIN), a. t. (2012). The 2012 ageing report, economic and budgetary projections for the 27 EU Member States (2010–2060). European Commission, DG ECFIN & AWG. European Commission, Brussels

Eurostat (2014) Eurostat T, EU statistics on regions and cities. Eurostat regional yearbook. In Eurstat regional yearbook (doi:10.2785/54659 ed.). Luxembourg: Publications O ce of the European Union

Exleya CA (2007) A critical examination of home care: end of life care as an illustrative case. Soc Sci Med 65:2317–2327

Fogg B (2009) A behavior model for persuasive design. Persuasive'09. Clairmont: ACM ISBN 978-1-60558-376-1/09/04

Foucault M (1988) http://foucault.info/documents/foucault.technologiesofself.en.html. Retrieved from Foucault.Info: http://foucault.info/documents/foucault.technologiesofself.en.html

Fox SD (2013) Tracking for health. Pew Internet Research, Pew Internet Research

Fried LT (2001) Frailty in older adults: evidence for a phenotype. J Gerontol Ser A Biol Med Sci 56(3):M146–M156

Fritz TH (2014) Persuasive technology in the real world: a study of long-term use of activity sensing devices for fitness. CHI 2014, One of a CHInd. Toronto

Geraedts HA (2014) Adherence to and effectiveness of an individually tailored home-based exercise program for frail older adults, driven by mobility monitoring: design of a prospective cohort study. BMC Public Health 14:570

Geraerdts HA (2017) A home-based exercise program driven by tablet application and mobility monitoring for frail older adults: feasibility and practical implications. Prev Chronic Dis 14(160227):E12

Gobbens EA (2010) The Tilburg frailty indicator: psychometric properties. American Medical Directors Association

Gschwind YJ et al (2014) ICT-based system to predict and prevent falls (iStoppFalls): study protocol for an international multicenter randomized controlled trial. BMC Geriatr 14:91

Gschwind YJ et al (2015) ICT-based system to predict and prevent falls (iStoppFalls): results from an international multicenter randomized controlled trial. Eur Rev Aging Phys Act 12:10

Harcourt B (2015) Exposed. Havard University Press, Camebridge, UK

Himmel SZ (2016) Smart home medical technologies: users' requirements for conditional acceptance. i-com 15(1):39–50

Jovanov EM (2011) Body area networks for ubiquitous healthcare applications: opportunities and challenges. J Med Syst 35(5):1245–1254

Karapanos E (2015) Sustaining user engagement with behavior – change tools. INTERACTIONS.ACM.ORG

Klack, L. (2011). Future care floor: a sensitive floor for movement monitoring and fall detection in home environments. Wireless mobile communication and healthcare. pp 211–218

Leonardi CE (2009) Knocking on elders' door: investigating the functional and emotional geography of their domestic space. CHI 2009, April 4–9, 2009, Boston, MA, USA. Boston: ACM 978160558-246-7/09/04

Lupton D (2014) Self-tracking modes: reflexive self-monitoring and data practices. Imminent citizenships: personhood and identity politics in the informatic age

Lupton D (2016a) Digitised health, medicine and risk, health, risk & society. Health Risk Soc 17(7–8):473–476

Lupton D (2016b) The quantified self. Polity Press, USA

Lyon D (2009) Surveillance, power and everyday life. In: David L (ed) The Oxford handbook of information and communication technologies. Oxford University Press, Oxford

Machiko RT (2010) Smart home with healthcare technologies for community-dwelling older adults, smart home systems. InTech

Mann S (1997) Smart clothing: the "Wearable Computer" and WearCam. Personal Technol 1(1). Retrieved from http://n1nlf-1.eecg.toronto.edu/personaltechnologies/

Markopoulos PD (2009) A design framework for awareness systems, awareness systems. Springer London, London
Markopoulos P (2016) Reflections and advances in ambient intelligence. J Ambient Intell Smart Environ 8(5):491–499
Marston HR (2015) The design of a purpose-built exergame for fall prediction and prevention for older people. Eur Rev Aging Phys Act 12:13
Metaxas GM (2007) Daily activities diarist: supporting aging in place with semantically enriched narratives. INTERACT 2007. 4663, pp 390–403. Springer
Mynatt EE (2000) Increasing the opportunities for aging in place. CUU'00 Proceedings on the 2000 conference on Universal Usability. ACM, New York, pp 65–71
Norman (1993) Things that make us smarter. Diversion Books, New York
Norman D (2010) Living with complexity. Cambridge Massachusetts, London, England: MIT Press
Olson P (2014) Wearable tech is plugging into health insurance. (Forbes) Retrieved from Forbes: http://www.forbes.com/sites/parmyolson/2014/06/19/wearable-tech-health-insurance/#1498788b5ba1
Patel S (2012) A review of wearable sensors and systems with application in rehabilitation. J Neuroeng Rehabil 9:21
Percival JJ (2006) Big brother or brave new world? Telecare and its implications for older people's independence and social inclusion. Crit Soc Policy 26:888–909
Pino MB-S (2015) "Are we ready for robots that care for us?" Attitudes and opinions of older adults toward socially assistive robots. Front Aging Neurosci 7:141
Punie YD (2005) Dark scenarios in ambient intelligence: highlighting risks and vulnerabilities. SWAMI consortium to the European Commission under contract 006507, Information Society Technologies
Quantified Self London Meetup (2014) London QS meetup survey. Retrieved from Quantified Self: http://quantifiedself.com/2014/03/london-qs-meetup-survey/
Rolfson DM (2006) Validity and reliability of the Edmonton frail scale. Age Ageing 35:526–529
Ruckenstein M (2015) Beyond the quantified self: thematic exploration of a dataistic paradigm. New Media Soc 1(18)
Salomon RL (2010) iFall – case studies in unexpected falls. IEEE International Symposium on Industrial Electronics (ISIE) (pp 1645–1650). IEEE, Bari
Shih PH (2015) Use and adoption challenges of wearable activity trackers. iConference 2015 proceedings
Smarr CP (2012, Sep) Older adults' preferences for and acceptance of robot assitance for everyday living tasks. *Proc Hum Factors Ergon Soc Annu Meet* 56(1):153–157
Tacken MM (2005) Use and acceptance of new technology by older people. Findings of the international MOBILATE survey: enhancing mobility in later life. Geront Tech J 3:126–137
The Economist (2012) Technology quarterly Q1 2012. Retrieved from The Economist: http://www.economist.com/node/21548493
UNFPA (2011) Aging in the twenty first century, a celebration and a challenge. UNFPA and HelpAge International London. New York: United Nations Population Fund
Wolf G (2009) wired.com. Retrieved from https://www.wired.com/2009/06/lbnp-knowthyself/

Christel De Maeyer has over 25 years international experience in the Digital Media domain. Christel, holds a Master degree in Communication Science, New Media and Society in Europe, VUB – SMIT – Brussels, where she researched wearable devices and behavior change. In 2008 she became involved in the Persuasive Technology Lab at Stanford University, working on behavior design with the team of Dr. B. J. Fogg in the area of Peace Innovation and wearable tech. Christel is a researcher and lecturer at Artevelde University College, Ghent, Belgium; a PhD Candidate in User Centred Engineering Group, Department of Industrial Design, Eindhoven University of Technology http://be.linkedin.com/in/christeldemaeyer

Part III
Games for Health

Chapter 5
Using Technology to Increase Activity, Creativity and Engagement for Older Adults Through Visual Art

Alexander Paczynski, Laura Diment, David Hobbs, and Karen Reynolds

Abstract With an ageing population it is critical to develop strategies to assist older adults to remain physically and cognitively active and to reduce sedentary behaviour. Previous research has shown a positive relationship between art therapy and successful ageing, yet traditional art practices may be challenging for older adults. Virtual reality systems eliminate mess and the need for fine motor control, allowing people of all ages and abilities to access an alternate artistic environment. Digital art, created using novel software, has the potential to encourage physical activity, creativity and provide a leisurely experience. *Splashboard* uses the Microsoft Kinect camera and enables participation in art through virtual button activation. Through arm and body movements a multi-coloured digital canvas can be created, saved, printed and displayed. The software was trialled with 15 older adults within a residential aged care setting. During the art sessions the system tracked body position and hand movements. An exercise was integrated into *Splashboard* to assess reaction time, attention, memory and hand-eye coordination. Participant feedback on the joys and challenges of using *Splashboard* was collected via questionnaires. Results indicated that the software successfully engaged most participants, encouraged physical activity and cognitive thought, and allowed the residents to enjoy the process of creating art.

A. Paczynski • D. Hobbs (✉) • K. Reynolds
Medical Device Research Institute, College of Science and Engineering,
Flinders University, Adelaide 5042, Australia
e-mail: david.hobbs@flinders.edu.au

L. Diment
Medical Device Research Institute, College of Science and Engineering,
Flinders University, Adelaide 5042, Australia

Department of Engineering Science, University of Oxford,
OX1 3PJ Oxford, UK

H.R. Marston et al. (eds.), *Mobile e-Health*, Human–Computer Interaction Series,
DOI 10.1007/978-3-319-60672-9_5

5.1 Introduction

The global population in most developed countries is ageing, with United Nations projections indicating that the number of persons aged 60 or above is expected to more than double by 2050 and more than triple by 2100 (United Nations 2015). The United Kingdom has approximately 10.4 million older people (people aged 65 years and over) (Office for National Statistics 2012), with around 45% having a disability (Department for Work and Pensions 2012). Disability is defined as having a physical or mental impairment that has a substantial and long-term negative effect on a persons' ability to do normal daily activities (Equality Act 2010). As the life expectancy rises and the population ages, the total number of people with disabilities will increase. Improved healthcare and increased life expectancy are likely to reduce the prevalence of severe disability, but the occurrences of milder chronic diseases may rise (World Health Organization 2011).

Disability can discourage an active lifestyle, increasing the risk of developing other conditions such as cardiovascular disease or osteoporosis (Conn et al. 2011). Consequently, assisting older adults to improve their physical and cognitive well-being potentially prevents them from leading sedentary lives and increases their independence. For this reason, it is critical to develop technologies and strategies to assist older adults to become more active, by increasing physical movement and creativity for cognitive stimulation.

5.2 The Benefits of Creating Art

Studies have shown the potential benefits of engaging older people in visual arts. Fisher and Specht (1999) demonstrated that undertaking creative activities, such as painting, was linked to successful ageing by fostering a sense of competence, purpose and growth. Partaking in the creative process enabled older people to open themselves up to innovative and flexible thoughts that can be implemented in their daily lives. Engaging in art making gave older adults a sense of purpose, satisfaction, a means to escape from their worries and positive feelings about their self-worth (Fisher and Specht 1999).

LaPorte and colleagues suggested that the physical and cognitive well-being of older adults with dementia could be maintained or enhanced through recreational therapies such as art (LaPorte et al. 2003). The authors reported that those suffering from a cognitive impairment found comfort through undertaking artistic activities as they provided structure to their day and a means of communication. Additionally, those living with dementia felt a sense of achievement through their art.

Hannemann (2006) stated that "People with physical or mental challenges due to stroke, heart attack, dementia, or other serious factors have reported improved mood and self-esteem through artwork" (p. 62). An additional study by Cohen et al. (2006) showed that an intervention group that participated in art programs had a higher

physical health rating, with decreased doctor visits and fewer instances of falls and health problems, when compared to the control group that did not participate in the artistic activity. The study also reported an increase in morale for the intervention group (Cohen et al. 2006).

5.3 Utilising Technology to Make Art Accessible for People with Disabilities

As the benefits of art therapy become more widely known, a critical consideration is how to make art accessible to older adults who have a disability or who experience age-related impairments. The hands-on approach of most traditional art practices excludes many older persons with physical and cognitive impairments who may lack the necessary strength, coordination, dexterity and control of their hands to grip pencils, pens and paintbrushes.

With the emergence of the technological era, innovative systems and strategies to solve existing problems continue to be developed, with both virtual reality (VR) and augmented reality (AR) programs becoming more prevalent in art therapy. VR allows one to interact in an immersive, virtual, computer-generated environment in a physical way, whereas AR integrates virtual information into the real or existing environment. A computer with the relevant software and motion-tracking device can allow an individual to interact with a virtual environment without the need for complex control systems or fine motor control. Such technology has enabled children with a disability, and older adults in a residential care setting, to engage with and play music simply by moving their limbs (Tam et al. 2007; Raghavendra et al. 2010; Chau et al. 2012).

A review of interactive technologies that encourage creative engagement in art identified 14 interactive free or low-cost art programs that utilise a range of platforms, including the Apple iPad, Microsoft Kinect and desktop PC (Diment and Hobbs 2014a). Some open-source programs have been designed for the Kinect that create artistic effects in response to user's movements or voice, but these programs prove difficult for a user with an impairment, and the full breadth of user ability was rarely considered when they were developed. Many of the available programs have not been validated for users with an impairment, and so it is difficult to confirm their effectiveness for this population (Diment and Hobbs 2014a).

A pilot study trialling new software coupled with a Microsoft Kinect camera, with children with severe physical impairments, identified that despite their limitations, the children were able to create art through the use of a gesture-based virtual art program (Diment and Hobbs 2014b). The program was designed to track a participant's limbs, draw art while doing so, and record the amount of motion for each limb. As the trial progressed, it was noted that the children engaged with the program more, and an analysis of the data showed a trend towards increased limb motion (Diment and Hobbs 2014b).

Studies have investigated the benefits of using an off-the-shelf Nintendo Wii (consisting of a Nintendo console, a sensor and a handheld controller) with older adults in residential aged-care facilities, given the system's ability to encourage physical activity and stimulate upper body movement. Jung and colleagues found that participation in Wii games positively impacted the well-being of older adults compared to a control group who played traditional board games (Jung et al. 2009). Another study suggested that digital gameplay has the potential to train and uphold cognitive and motor abilities in aged care, identifying that a primary benefit was allowing seniors to simulate real-life activities that otherwise may be difficult to participate in (Marston et al. 2013).

Higgins and colleagues reported that staff in an aged-care environment believed that the Nintendo Wii offered an opportunity for older adults and individuals with a disability to improve their well-being. However, it was also the belief of staff that participation in Nintendo Wii games was not as effective for those individuals who were significantly impaired due to a physical or cognitive condition (Higgins et al. 2010). These observations highlight the need to address issues relating to both the *physical* interface between the user and the technology (termed the "human/technology interface" by Cook and Polgar (2008, p. 44) and the *cognitive* demand of the activity or game, when developing an accessible system for individuals with an impairment.

Keogh and colleagues used the "Nintendo Wii Sports" package with 34 older adults in a residential care setting, with the intervention group achieving significantly greater increases in bicep curl, muscular endurance, physical activity levels, and psychological quality of life, compared to the control group (Keogh et al. 2014). The authors noted that after some initial reluctance and anxiousness from the participants, the intervention group developed a sense of empowerment and achievement and commented that the games were fun and provided an avenue for greater socialisation (Keogh et al. 2014).

A recent meta-analytic review from 36 studies to examine the physical and cognitive impacts of digital games on older adults identified that playing digital games is effective in improving their physical balance and balance confidence, functional mobility, executive function and processing speed (Zhang and Kaufman 2015). Key findings from the review included that playing digital games improves the balance of older adults, both those living in the community and those living in nursing homes, and that the participants' ages or the amount of time spent playing the game are related only weakly to affect size, with the direction of the relationship inconclusive (Zhang and Kaufman 2015).

The following study demonstrates the feasibility of using digital technologies to promote physical activity, stimulate cognitive function and encourage creativity through observing how older adults engaged both physically and cognitively with a visual art computer program.

5.4 Harnessing Technology to Enable Older Adults to Create Digital Art: A Case Study

With the emergence of new and smarter technologies, the reliance on tangible devices as the only means of providing an input to a computer program is decreasing. As described earlier, new technologies now recognise gestures and movements as control inputs, paving the way for new "non-touch" interfaces. With the importance of the user interface in mind, the Microsoft Kinect was identified as a viable option for further exploration as it allows the user to interact with the system via hand gestures, limb movement and voice control. There is no need to hold a physical device or activate potentially confusing and inaccessible buttons.

A study examining how older adults respond to and interact with a new computer program using a Kinect camera to create digital artwork was performed, as there was interest in understanding how these sorts of technologies can facilitate not only increased movement but also cognitive stimulation and creativity.

5.5 Overview of the Technology

The *Kinect Virtual Art Program* (KVAP) was originally developed to integrate with a Microsoft Xbox 360 camera, to enable an individual to draw and create art simply by moving their limb through space while interacting with a virtual world. KVAP was designed by engineers in consultation with therapists, special needs teachers and disability professionals to meet the needs of children with severe physical impairments. The program encouraged experimentation and exploration, engaging participants cognitively through the creation of art as well as physically through limb movement (Diment and Hobbs 2014b). KVAP was further developed and upgraded to function on the latest Kinect sensor for the Xbox One system, with the software being renamed *Splashboard*. The new design sought to engage a broader population, and a subsequent trial of the software focused on its use in a residential aged-care setting.

The newest Kinect (Kinect for Windows v2) was released in 2014, along with the Xbox One Microsoft console. It utilises a "time-of-flight" camera, which works by emitting light and measuring the time taken to return to the sensor. This method provides an accurate estimation of depth and enables a precise reconstruction of the environment (Meisner 2013).

5.6 The *Splashboard* Program

Splashboard uses an off-the-shelf Microsoft Kinect v2 (Microsoft 2015) and its corresponding Software Development Kit connected to a computer rather than an Xbox unit. In combination with the new camera, *Splashboard* is faster and more efficient than KVAP and incorporates new visual and auditory effects that relate to the movements of the user to encourage movement, creativity and unstructured exploration. *Splashboard* was designed to be simple and intuitive and to accommodate the user and their potential lack of motor control, muscle strength or cognition. Being gesture-based, *Splashboard* doesn't require a physical interface to hold or manipulate.

Splashboard tracks the changes in *x, y* and *z* coordinates of various body parts over time. The tracked limbs are then responsible for painting in the virtual environment. Given that the program is specifically targeted at people with limited motor capabilities, a virtual button activation system is used. Colourful squares and icons are used to create a virtual overlay on the video display of the real world. As a body part passes through one of the buttons, for example, the blue square, the paint colour produced by the motion of that particular body part becomes blue. The same principle applies for all other coloured buttons. The screen layout of *Splashboard* is shown in Fig. 5.1.

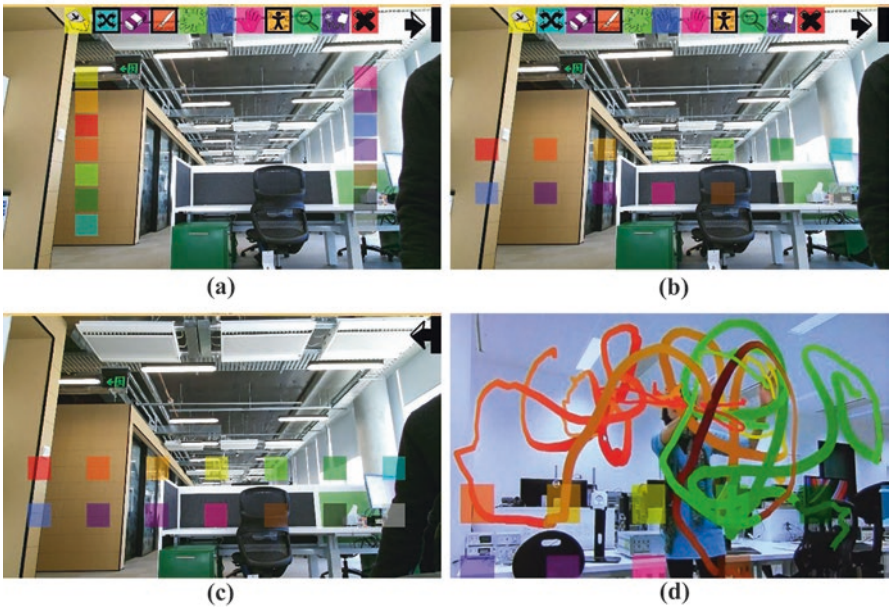

Fig. 5.1 (**a**) Menu bar visible along the top of the screen, with a vertical button layout on either side of the screen. (**b**) Menu bar visible along the top of the screen, with a two-line horizontal button layout. (**c**) Menu bar hidden with a two-line horizontal square button layout. (**d**) Sample *Splashboard* painting

Fig. 5.2 The *Splashboard* interactive menu bar

Fig. 5.3 The initial on-screen assessment exercise that the participant was required to complete prior to using *Splashboard*

The interactive menu bar (see Fig. 5.2) was designed to be visually simple and informative. Moving from left to right, buttons exist for taking a screenshot, altering a virtual button positioning, erasing/clearing, painting, toggling special effects, tracking the left hand, tracking the right hand, tracking all limbs, zooming, hiding the image and exiting the program. The buttons are activated by hovering over the desired function.

5.7 Pilot Trial with Older Adults

A pilot trial of *Splashboard* was conducted in a residential aged-care facility to obtain data on how a virtual reality art program can affect the physical and cognitive well-being of residents. Fifteen participants were given an opportunity to use *Splashboard* as part of a suite of leisure activities that the aged-care centre typically offers. Inclusion criteria for the 6-week trial included being 65 years of age or older, being a resident of the aged-care facility, having visual acuity to a distance of two metres (with or without a visual aid) and having the ability to independently and intentionally move one or more limbs.

Quantitative data in the form of limb movement, range of motion and the length of time that *Splashboard* was used was automatically tracked and stored by the program. Heart rate information was measured using an off-the-shelf ‘Fitbit Charge HR’ (Fitbit 2015) that participants were asked to wear on their left wrist during each session.

Qualitative responses were collected via two questionnaires. The first questionnaire profiled the participant pre-trial (to gain a better understanding of the user and their levels of enjoyment), and the second questionnaire was administered at the end of the trial (to provide an insight into the user experience, what participants found enjoyable and the challenges that were faced). Some participants were unable to respond to the questions, so the staff answered on their behalf. Initial background responses indicated that participants were affected by one or more medical

conditions, with most participants having dementia or depression or recovering from a stroke.

Under staff supervision, participants were free to use the program whenever they desired. Each participant was allocated a unique identification number that could be tracked over the trial period. A short assessment exercise (see Fig. 5.3) provided an indication of reaction time, attention, memory, hand-eye coordination and the ability to follow instructions. The exercise was integrated into the *Splashboard* system, appeared upon start-up and required the participant to follow a series of prompts on the screen. The assessments occurred at the beginning of each session to determine if *Splashboard* was having an effect on the participant's ability to complete the exercise over time.

5.8 Results

Fifteen residents (average age 84 ± 8 years, minimum = 69 years, maximum = 96 years) trialled the *Splashboard* system for 6 weeks. The system was set up during the day in a spacious room with a widescreen television for residents to interact with. The average session length was 11.6 min, and the average number of sessions per participant was four. Staff noted that most participants were able to engage physically with *Splashboard* without discomfort.

While *Splashboard* can track many parts of the body, this pilot study focused on tracking the left and right hands and the lower spine only. Movements of the hands indicated upper limb function of a "typical user" while movement of the lower spine indicated how much the person moved their base of support.

5.9 Individual Case Study

From the overall cohort, a representative participant (participant 4) was selected to highlight the effects of using the program. Aged-care staff indicated that this participant had suffered a stroke and had elevated blood pressure, depression and short-term memory loss. Over the 6-week period, this participant used *Splashboard* nine times for an average of 17 min (min = 7 min, max = 39 min). Movement in all three dimensions for the upper body relative to the lower spine is shown in Fig. 5.4a and 5.4b.

During each of the nine sessions, this participant moved both their upper limbs at least 400 m, with notable exceptions for sessions five and eight, where total limb movements approached 2000 m and 1000 m per arm, respectively, in a single session. With the exception of session one, most of the arm movement was symmetrical, as indicated in Fig. 5.4a. Over time, the participant gradually increased their arm velocity across sessions, and the average velocity per arm was relatively symmetrical (see Fig. 5.4b). Heart rate data showed a 43.5% increase between minimum

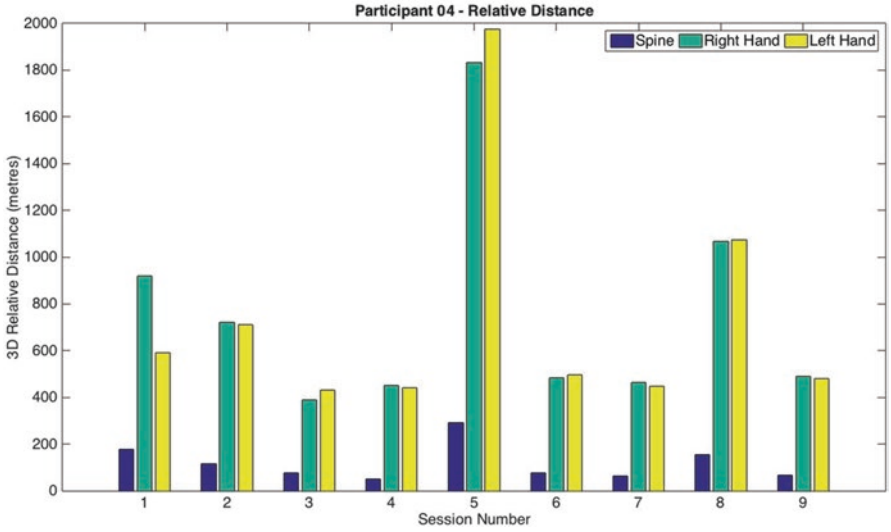

Fig. 5.4a Three-dimensional distance travelled for the left and right hands relative to the lower spine

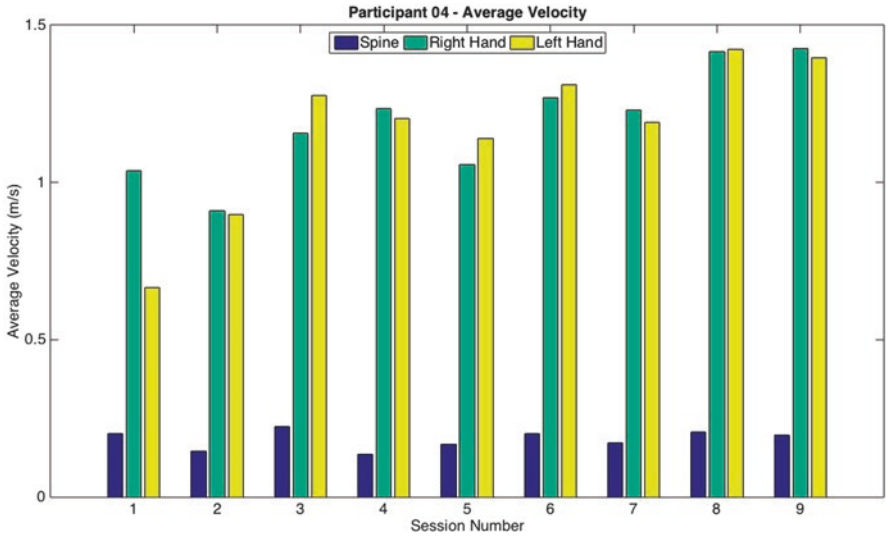

Fig. 5.4b Average velocity for lower spine, left and right hands

and peak heart rates during *Splashboard* use. While the participant indicated right hand dominance on their pretrial questionnaire, the data does not indicate a significant hand preference. This suggests that *Splashboard* encouraged uniform bilateral upper body movement.

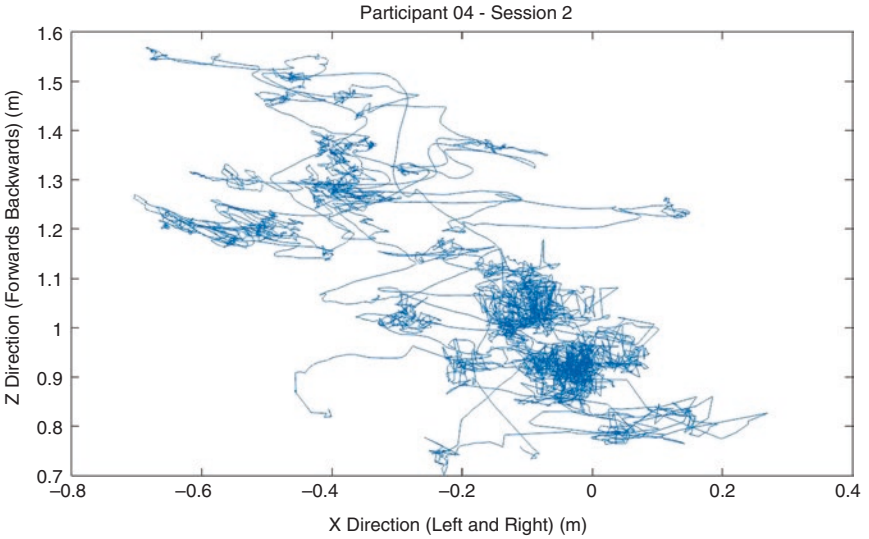

Fig. 5.5 Session 2 – Movement of the lower spine tracked in *X* and *Z* directions. The positive *X* direction represents movement to the right, and negative *X* direction represents movement to the left

Table 5.1 Assessment exercise times for participant 4

Session no.	Length (s)	Session no.	Length (s)
1	Incomplete	6	40.46
2	17.33	7	58.48
3	27.14	8	32.73
4	36.87	9	10.1
5	4.61		

Figure 5.5 shows a plot of the lower spine movement in the *X* (left and right movement, parallel with screen) and *Z* planes (forward and backward movement, perpendicular to screen) to highlight the range and amount of body movement that occurred during session two for this participant. The zero point on the *X* axis marks the position of the Kinect sensor.

The spine trace indicates that the participant showed very little side-to-side (*X* direction) and forward-backward (*Z* direction) movement, with a preference for moving to their left compared to their right in this instance.

Data from the pre-*Splashboard* assessment exercise shows variable response times, making it difficult to conclude if this participant improved their attention and/or reaction time over 6 weeks. 'Incomplete' means that the participant failed to complete the assessment in the allocated time, which was 1 min. The data indicates that this participant was attentive and able to follow instructions. The time of completion for each assessment exercise is shown in Table 5.1. Overall, the time required

Fig. 5.6 Example artwork that was created by participant 4

to complete the task varied significantly across and between all participants, with some participants being unable to complete the exercise.

Examples of the art that this particular participant created using *Splashboard* are shown in Fig. 5.6. Staff noted that the participant engaged well with *Splashboard*, smiling and whistling while creating art. The participant took particular interest in the technology and how the program worked. This insight may indicate a higher level of cognitive function. Staff noted that participant 4 would smile, whistle and throw their arms around while using *Splashboard*, saying "*that was good fun*", after a session.

5.10 Overall Pilot Trial Trends

Table 5.2 shows the heart rate values that were recorded via the *Fitbit Charge HR* for each participant during *Splashboard* use. The data shows that all participants experienced an increase in heart rate compared to their resting heart rate, as would be expected when engaging in an upright activity. Participants that used *Splashboard* for longer periods of time experienced greater increases in heart rate.

From the 15 participants, six completed four or more sessions, five finished two sessions and the remaining four completed only one session. Out of the six participants who engaged in four or more sessions, five recorded higher maximum distances travelled in at least one of their sessions than those who had fewer sessions.

All participants completing more than one session recorded lower distances travelled in their final session than in their first session. From the six people who completed four or more sessions, four recorded higher distances travelled with their arms in a middle session. The remaining seven participants recorded their maximum distance travelled during their first session, indicating that the initial engagement with *Splashboard* was high before decreasing.

It is likely that residents were initially excited by the novelty of a new activity when *Splashboard* was first introduced, providing them with extra motivation to engage and hence record high levels of movement in their initial session. A key factor for the amount of distance travelled is the session length. Sessions were unstructured, and session length was not controlled during the trial as the length of the

Table 5.2 Heart rate (HR) values per participant during *Splashboard* use

Participant no.	Minimum HR	Average HR	Peak HR	No. of sessions
01	89	102	132	9
02	84	88	96	6
03	91	101	109	2
04	85	101	122	9
05	87	88	94	5
06	90	95	104	2
07	77	77	93	4
08	86	96	115	15
09	89	102	113	1
10	90	102	116	2
11	65	68	73	1
12	95	103	113	2
13	85	87	107	2
14	95	104	111	1
15	58	58	59	1

session was used as an indicator of enjoyment and sustained activity. A longer session length allows more opportunity for motion and increases the likelihood that a greater distance is travelled. Not restricting the participants to a set task meant that they could engage with *Splashboard* to creatively explore the potential of the program.

The average velocity was calculated post-session to determine if the rate of limb movement increased over the 6-week trial period. From the 11 participants who completed more than one session, average velocity increased in one or more tracked body parts for seven participants, indicating that while the session times for most participants decreased over time, the amount of movement per second increased.

Key indicators for *Splashboard* enjoyment were session length, the number of sessions and qualitative responses provided by participants and staff. Table 5.3 shows the average session length for all participants and the number of sessions completed. Session lengths varied for many reasons with 14 of the 15 participants recording an average session length of 5 min or greater.

Qualitative responses indicated that 11 of the 15 participants enjoyed their experience with *Splashboard*, with a few of the participants expressing their desire to use it again. The bright colours that formed the art on the screen were enjoyed by most participants. Across all participants a common response was that *Splashboard* made them tire due to the amount of upper limb activity that was required to create art within the program. Staff also noticed this and referred to it as *incidental exercise* and that participants were *engaging in exercise without realising it*, therefore making it a positive experience.

The four participants who did not enjoy using *Splashboard* could not articulate why they did not enjoy the activity; however, one participant said that *Splashboard* made them feel anxious, so they didn't engage with the program again, and another

Table 5.3 Average *Splashboard* session times (min) and the number of sessions per participant (*N*)

Participant no.	Average session length (min), no. of sessions (*N*)	Participant no.	Average session length (min), no. of sessions (*N*)
01	43 min, *N* = 9	09	7 min, *N* = 1
02	6 min, *N* = 6	10	11.5 min, *N* = 2
03	8.5 min, *N* = 2	11	6 min, *N* = 1
04	17 min, *N* = 9	12	7 min, *N* = 2
05	7 min, *N* = 5	13	19.5 min, *N* = 2
06	3.5 min, *N* = 2	14	6 min, *N* = 1
07	10.5 min, *N* = 4	15	5 min, *N* = 1
08	16 min, *N* = 15		

seemed confused and tried to physically touch the TV screen that was displaying the virtual art rather than to engage with it like a mirror. One participant found it comforting to see themselves on the TV screen, while another found this confronting.

As explained earlier, prior to using *Splashboard* each participant was presented with a cognitive assessment. Ten of the participants completed at least one cognitive assessment. The response times were highly variable with no trends identified, possibly due to the medical history of the participant and because participants were unaware that the interactive prompt was an assessment, meaning they didn't complete or interact with it with a sense of urgency. Some participants had difficulty understanding the prompt, so the assessment was marked as incomplete. However, participants who used *Splashboard* more often consistently showed better ability to complete the cognitive assessment, indicating a familiarity with the exercise.

5.11 Sub-cohort Trends

Four out of five participants affected by stroke enjoyed using *Splashboard*, with the other participant reporting the experience as 'overwhelming'. Limb movement data indicated that all participants in this sub-cohort were able to produce both above-average upper body motion and average velocities and four of five participants felt that *Splashboard* was beneficial for their physical and cognitive well-being. Some participants had trouble with verbal communication, so *Splashboard* provided an opportunity to creatively express themselves in a way that was previously not possible for them. One participant could no longer write with either hand after suffering a stroke, but the accessibility of *Splashboard* provided this individual with a chance to participate in artistic activities.

For the sub-cohort with dementia/memory impairment, three of the nine participants completed four or more sessions with *Splashboard*. Four participants felt that *Splashboard* was beneficial for their cognitive health and five participants believed *Splashboard* was beneficial to their physical well-being.

All participants affected by depression completed two or more sessions with Splashboard and four out of five completed four or more sessions. Limb movement data indicated that all participants were able to produce above-average upper body movements. Qualitative responses from this sub-cohort indicated that three participants felt happier after having used *Splashboard*. The opportunity to be creative was satisfying for this sub-cohort.

5.12 Character Profile Analysis

Participants were asked to respond to a questionnaire following the 6-week trial. One question required participants to select words from a list to create a character profile, based on a simplified Myers-Briggs-type personality test. It was hypothesised that this character profile would show similar personality traits amongst the participants that enjoyed interacting with *Splashboard* the most and/or similar traits amongst those who did not enjoy *Splashboard*. Of the 15 participants, 12 provided responses to the character profile section of the questionnaire.

Figure 5.7 shows the responses selected by the six participants who completed four or more sessions with *Splashboard* in red, while responses in blue are from participants who completed less than four *Splashboard* sessions. The results are not significantly different between the two groups. However, on individual questions, responses indicate that participants that were sociable, creative and easy-going

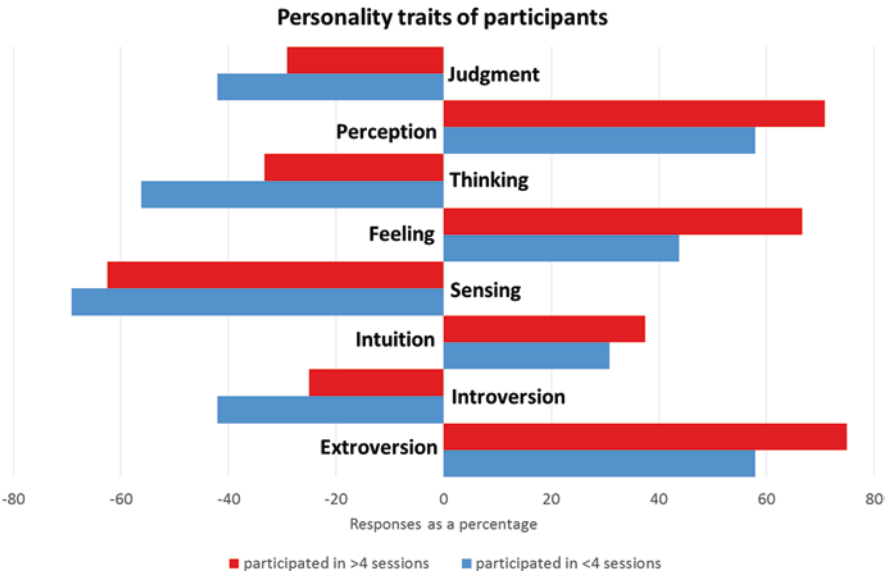

Fig. 5.7 Character profile trends. Red bars represent participants who completed four or more *Splashboard* sessions; blue bars represent participants who completed less than four *Splashboard* sessions

tended to enjoy *Splashboard* and the process of creating virtual art. Conversely, participants who did not participate in the trial as often (i.e. they completed less than four sessions over the trial period) favoured many of the opposite traits, such as being reserved and careful.

5.13 Efficacy of Recording Heart Rate Using the FITBIT Charge HR

The Fitbit Charge HR appeared to collect more reliable data if the session length was longer compared to shorter sessions. Errors from the Fitbit were potentially due to incorrect positioning of the Fitbit on the participant's wrist (which was fitted by staff). The Fitbit is required to fit snugly on the wrist as described by the device manufacturer in order to function optimally, and this aspect may have been overlooked when being fitted to participants' wrists given individual wrist size differences.

Since participants were using their arms to paint, noise via movement may have been introduced into the signal. To minimise movement-generated noise, the Fitbit was placed on the left wrist, with the assumption that the majority of participants would favour their right hand when using *Splashboard*. Analysis of the movement data showed that this was not the case, with many participants demonstrating bilateralism or preferentially using their nondominant hand.

5.14 Pilot Trial Overview

The pilot trial results suggest that *Splashboard* can provide a leisurely and creative activity while encouraging physical motion and cognitive thought. The trial demonstrated that older participants with a significant medical history were able to engage in an activity that otherwise may no longer be possible. This study also provided an understanding of the groups of people that may benefit from a virtual art program. Many participants were disappointed to hear *Splashboard* was leaving the facility at the conclusion of the trial. A reflection from the lifestyle coordinator highlights the success of the pilot trial and the impact it had on residents:

> The very first day we trialled *Splashboard* with a participant, many staff were in tears. For someone who can no longer verbalise her needs it was very emotional to see her so engaged and enthralled by *Splashboard*. She was totally living in the moment and was able to express herself through art. Many of us noticed improvements in her mood and also assisted to decrease her behaviours and anxiety.
>
> Families were overjoyed that their loved one was considered to participate in something new and exciting and some were able to see first-hand their loved one participating in something they didn't realise they could still do. Staff, visitors and customers would sit at the back of the room and watch participants with amazement and were blown away by the technology.

5.15 Conclusion

The results from the pilot trial indicate that a virtual art program can encourage both creativity and physical activity via upper limb movement and body motion for a cohort of older adults. The system provided an opportunity for some residents to creatively express themselves where they can't do so with traditional methods. Participants felt that *Splashboard* was beneficial to their physical and cognitive well-being, with a few participants reporting feeling happier after using *Splashboard*. Staff were positive about the program and enjoyed seeing their residents engaging with the technology, recognising that it was also contributing towards "incidental exercise" as well as cognitive stimulation. Given the positive pilot trial results, there is scope for *Splashboard* to be trialled with a larger cohort to investigate which populations can benefit the most from using *Splashboard,* the effect that ongoing use may have on balance in older adults and if ongoing use can improve cognitive well-being.

Digital technologies that promote physical and cognitive well-being for older persons, especially those with a disability and other comorbidities, have the potential to increase independence and decrease the risk of people developing further health complications that are associated with sedentary behaviour and reduced cognitive activity. Digital art technologies enable older adults who have a disability or who experience age-related impairments to benefit from art therapy when traditional hands-on approaches are inaccessible.

References

Callaham J (2015) Kinect for Windows v2 sensor sales end, developers can use Xbox One version instead. Retrieved 7 December 2015, from: http://www.windowscentral.com/kinect-windows-v2-sensor-sales-end-developers-can-use-xbox-one-version

Chau T, Memarian N, Leung B, Treherne D, Hobbs DA, Worthington-Eyre B, Lamont A, Pla-Mobarak M (2012) Home-based computer vision access Technologies for Individuals with severe motor impairments. In: Augusto JC, Huch M, Kameas A, Maitland J, McCullagh P, Roberts J, Sixsmith A, Wichert R (eds) Handbook of ambient assisted living – Technology for Healthcare, rehabilitation and well-being. IOS Press, Amsterdam, pp 581–597

Cohen GD, Perlstein S, Chapline J, Kelly J, Firth KM, Simmens S (2006) The impact of professionally conducted cultural programs on the physical health, mental health, and social functioning of older adults. The Gerontologist 46(6):726–734

Conn VS, Hafdahl AR, Mehr DR (2011) Interventions to increase physical activity among healthy adults: meta-analysis of outcomes. Am J Public Health 101(4):751–758

Cook AM, Polgar JM (2008) Cook & Hussey's assistive technologies, principles and practice, 3rd edn. Mosby Elsevier, St. Louis

Crawford S (2012) How Microsoft Kinect Works. Retrieved 22 January 2016, from: http://electronics.howstuffworks.com/microsoft-kinect.htm

Department for Work and Pensions (2012) Family Resources Survey. ISBN 978-1-78153-035-1. Retrieved 7 December 2015, from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/222839/frs_2010_11_report.pdf

Diment LE, Hobbs DA (2014a) Interactive technologies that engage children with disabilities in visual art – a review. In *Proceedings of the 2014 Australian Biomedical Engineering Conference* (ABEC), Canberra, Australia, August 2014

Diment LE, Hobbs DA (2014b) A gesture-based virtual art program for children with severe motor impairments – developments and pilot study. J Assistive Rehabil Ther Technol 2(23206). doi:10.3402/jartt.v2.23206

Fisher BJ, Specht DK (1999) Successful aging and creativity in later life. J Aging Stud 13(4):457–472

Fitbit (2015) Charge HR, Retrieved 15 December 2015, from: https://www.fitbit.com/au/chargehr

Gantt C (2013) iFixit opens up the new Xbox One Kinect sensor to see what's inside. Retrieved 7 December 2015, from: http://www.tweaktown.com/news/34077/ifixit-opens-up-the-new-xbox-one-kinect-sensor-to-see-whats-inside/index.html

Hannemann BT (2006) Creativity with dementia patients. Gerontology 52(1):59–65

Higgins HC, Horton JK, Hodgkinson BC, Muggleton SB (2010) Lessons learned: staff perceptions of the Nintendo Wii as a health promotion tool within an aged-care and disability service. Health Promot J Austr 21(3):189–195

Jung Y, Li KJ, Janissa NS, Gladys WLC, Lee KM (2009) Games for a better life: effects of playing Wii games on the well-being of seniors in a long-term care facility. In: Proceedings of the sixth Australasian conference on interactive entertainment, USA. doi:10.1145/1746050.1746055

Keogh JWL, Power N, Wooller L, Lucas P, Whatman C (2014) Physical and psychosocial function in residential aged-care elders: effect of nintendo wii sports games. J Aging Phys Act 22:235–244

LaPorte KM, Melo L, Stanley S, Zeltzer BN (2003) Arts therapies promote wellness in elders. (clinical report). Behav Healthcare Tomorrow 12:7

Marston HR, Greenlay S, van Hoof J (2013) Understanding the Nintendo Wii and Microsoft Kinect consoles in long-term care facilities. Technol Disabil 25(2):77–85

Meisner J (2013) Collaboration, expertise produce enhanced sensing in Xbox One. Retrieved 7 December 2015, from: http://blogs.microsoft.com/blog/2013/10/02/collaboration-expertise-produce-enhanced-sensing-in-xbox-one/

Microsoft (2015) Kinect Sensor for Xbox One, Retrieved 15 December 2015, from: http://www.microsoftstore.com/store/msusa/en_US/pdp/Kinect-for-Xbox-One/productID.307499400

Office for National Statistics (2012) 2011 Census: Population Estimates for the United Kingdom, 27 March 2011. Retrieved 7 December 2015, from: http://www.ons.gov.uk/ons/rel/census/2011-census/population-and-household-estimates-for-the-united-kingdom/stb-2011-census--population-estimates-for-the-united-kingdom.html

Raghavendra P, Murchland S, Shiosaki P, Hobbs DA (2010) Enabling children with severe physical disabilities using the virtual music instrument. In: Baxter P, Hart HM (eds) Developmental medicine and child neurology. Blackwell Publishing, Oxford. Australasian Association for Cerebral Palsy and Developmental Medicine (AusACPDM) Christchurch, New Zealand, p 45

Tam C, Schwellnus H, Eaton C, Hamdani Y, Lamont A, Chau T (2007) Movement-to-music computer technology: a developmental play experience for children with severe physical disabilities. Occup Ther Int 14(2):99–112

United Nations (2015) 'World Population Prospects: 2015 Revision'. Press release retrieved 1 August 2016, from: http://www.un.org/en/development/desa/population/events/pdf/other/10/World_Population_Projections_Press_Release.pdf

World Health Organization (2011) Global health and aging, NIH Publ no. 117737; 1(4):273–277

Zhang L (2013) Kinect Coordinate Space. Retrieved 21 December 2015, from: http://2.bp.blogspot.com/q9uwRQSp0zQ/USIKLoqjfII/AAAAAAAAAK8/XXCUHNVjjLk/s1600/skeleton+space.png

Zhang F, Kaufman D (2015) Physical and cognitive impacts of digital games on older adults: a meta-analytic review. J Appl Gerontol 1–22

Alexander Paczynski is a biomedical engineer working for Medical Equipment Management in the Northern Territory, Australia. His primary role is to provide technical expertise, support and remedial maintenance of medical equipment in metropolitan areas and remote communities. Alexander graduated from Flinders University with first-class honours in biomedical engineering. His interests lie in rehabilitative technologies, medical equipment design and improving healthcare accessibility.

Laura Diment is a John Monash scholar. She is studying for her doctorate in rehabilitation engineering at the University of Oxford, and she teaches undergraduate engineering courses. Her previous work for the Medical Device Partnering Program in South Australia supported the development of novel medical technologies and developed her interest in personalized rehabilitation devices. Her current research focus is on improving the comfort of prosthetic limbs.

David Hobbs is a biomedical and rehabilitation engineer within the Medical Device Research Institute at Flinders University. He has extensive industry experience within the rehabilitation engineering and assistive technology sector, having worked in the disability sector for 9 years before taking up an academic role at Flinders University. David is a Fulbright scholar and a Churchill fellow and is completing his PhD in rehabilitation engineering, which is focussing on improving upper limb sensation and function for children with an impairment.

Karen Reynolds is Matthew Flinders' distinguished professor of biomedical engineering at Flinders University and a director of the University's Medical Device Research Institute. Her research interests are aimed at developing new technologies for improved healthcare. She developed and leads the award-winning Medical Device Partnering Program in South Australia, a programme that supports the development of cutting-edge health technologies through unique collaborations between researchers, industry, end-users and government.

Chapter 6
Can Mobile Digital Games Benefit Older Adults' Health?

Emmanuel Duplàa, David Kaufman, Louise Sauvé, Lise Renaud, and Alice Ireland

Abstract Aging adults face many challenges, including declining physical and cognitive abilities, loss of companions and social support, family changes, loss of professional identity, changing lifestyles, and increasing likelihood of developing chronic and debilitating disease. Evidence suggests that digital games can improve older adults' quality of life through improved physical, cognitive, and social health as well as general psychological wellbeing and emotional health. Benefits demonstrated in research studies have varied with game characteristics, study methodologies, and outcome measures, so generalising across studies is difficult, but our review highlights the potential for mobile digital games to improve older adults' lives as they increasingly appear on common, accessible mobile devices.

6.1 Introduction

The proportion of people aged 60 and older is increasing faster than other age groups and is expected to increase to two billion by 2050 (World Health Organization 2002). In the USA, one million people reach the age of 65 each year, and in 2020, almost 30% of the population will be over 65 (Allaire et al. 2013). In Canada in 2010, almost five million people were 65 years of age or more, and by 2036, there will be more than ten million (Human Resources and Skills Development Canada

E. Duplàa (✉)
Faculty of Education, University of Ottawa,
145, Jean-Jacques-Lussier, Ottawa, ON, K1N 6N5, Canada
e-mail: eduplaa@uottawa.ca

D. Kaufman • A. Ireland
Faculty of Education, Simon Fraser University, Burnaby, BC, Canada

L. Sauvé
Department of Education, Téléuniversité, Université du Québec, QC, Canada

L. Renaud
Faculty of Communication, Université de Québec à Montréal, Montréal, QC, Canada

H.R. Marston et al. (eds.), *Mobile e-Health*, Human–Computer Interaction Series,
DOI 10.1007/978-3-319-60672-9_6

2011). Aging older adults face many challenges, including declining physical and cognitive abilities, loss of companions and social support, family changes, loss of professional identity, changing lifestyles, and increasing likelihood of developing chronic and debilitating disease.

Information communication technologies (ICTs) can offer ways to mitigate these challenges. Older adults increasingly use ICTs in their daily lives. ICTs, including digital games and mobile technologies, can help to improve older adults' safety at home, provide more access to information, increase family and social interaction, and increase older adults' life satisfaction and self-esteem (Fausset et al. 2013; Hwang et al. 2011).

Both digital games and mobile technologies are increasingly popular among older adults. In 2007, 27% of Canadian 45–64-year-olds and 36% of those 65 and over were playing digital games, positioning games as this population's third most common technology-related activity in that year, after email and online search (Statistics Canada 2007). In the USA, 78% of adults aged 65+ owned cell phones in 2015 and 30% owned smartphones, while the percentage of smartphone owners among all adults had increased from 35 to 68% since 2010 (Anderson 2015). In 2014 in Canada, 61% of seniors owned cell phones and 14% owned smartphones (Oliveira 2014). Thirty-two percent of Americans aged 65+ owned tablets in 2015, while 45% of all adults did so – an increase from only 4% in 2010 (Anderson 2015).

While their popularity has grown, digital games have become effective ways to enhance older adults' health and quality of life. They can engage players physically, mentally, and socially, educate them about health behaviors, support disease management and rehabilitation, and promote change to healthier activities and lifestyle choices (Wattanasoontorn et al. 2013). While research has documented benefits of digital gameplay on computers and game consoles, mobile games' potential in these areas is just beginning to be realized and studied.

This chapter reviews the potential benefits of mobile digital games for older adults' health and quality of life. Because research on mobile digital games is relatively new, the review relies on a qualitative meta-analysis (Bland et al. 1995) of research on digital games in general, summarizing areas in which evidence has been found for health-related benefits for older adults. This is extended to include game examples, whether or not rigorously evaluated, specifically for mobile games. The overall purpose of this chapter is to summarize key benefits of digital games for older adults' health and quality of life and to point to how these are likely to be realized in the near future.

6.2 Older Adults, mHealth, and Digital Games

Statistics Canada (2014) defines older adults as those aged 65 and older, but some reports distinguish a next generation aged from 55 to 64 years (Statistics Canada 2007). Definitions vary in the literature on digital games, with some studies

including adults starting at age 55. No studies have focused on the oldest old – adults aged 85 years or more (Marston et al. 2016).

The term "mHealth" has evolved from earlier terms describing applications of technology to health. Initially, the definition of "telemedicine" by Perednia and Allen (1995) was one of the most cited in the medical and paramedical literature, covering the use of communication and information technologies to deliver medical services remotely. The term grew to include clinical acts and the doctor-patient relationship, mediated by technology (e.g., Serafini 1995; Strode et al. 1999).

More recently, the concept of "eHealth" has appeared, based on the analogy with other e-domains such as eBusiness and eLearning. This combines medical computing with a business development perspective that views patients as clients who are actively involved in managing their own health, supported by technology (Alvarez 2002; Eysenbach 2001). It also extends medical training beyond students and medical staff to the general public through sites and applications including digital games (Raffelini 2005). Today, by extension, "mHealth" is defined as a component of eHealth: "mHealth or mobile health is the realization of medical and public health supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices" (Misha 2011, p. 6). mHealth extends telehealth in part by linking patients with medical personnel through convenient devices and improving medical data collection and patients' access to health care (Agarwal and Lau 2010). Several recent studies have documented mHealth applications for older adults (Baldwin et al. 2015; Kampmeijer et al. 2016; Silva et al. 2015). However, games are mentioned rarely in these reviews.

6.3 Older Adults and Quality of Life

Digital games are often cited as tools to improve quality of life for older adults. Although it has been difficult to build a consensus on what "quality of life" means (Kuyken 1995), the most widely used definition is that of the World Health Organization (1993). This provides a context for our review, defining quality of life as an individual's perception of their position in life, in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards, and concerns. It encompasses interrelated dimensions including a person's physical health, psychological state, level of independence, social relationships, personal beliefs, and relationships with characteristics of their environment. Chen et al. (2012) similarly define quality of life as a multidimensional concept that includes individual subjective perceptions on physical health, psychological state, relationships, and interactions with the environment. Four dimensions of health-related quality of life that have been studied with respect to digital games and older adults are physical health, cognitive abilities, social connectedness, and subjectively reported psychological well-being.

6.3.1 Physical Health

Aging brings about a decline in physical capacity. Usually from age 75 (although this varies with the individual), older people require different levels of daily support services to maintain their independence in the face of chronic health issues and/or cognitive problems (Daniel 2012). Physically, older adults are at increased risk of falls and major health risk factors. These risk factors include impaired muscle strength and poorer postural balance (Jorgensen et al. 2013) as well as fatigue, exhaustion, slow gait, and unintentional weight loss (Daniel 2012). For example, in 2009, 8.3% of men and 9.8% of women aged 65 or older were injured seriously enough to limit their usual activities, and 63.7% of these injuries were due to falls (Statistics Canada 2015). To overcome this, physical exercise is often recommended for the frail elderly as an intervention to restore muscle strength and agility (Daniel 2012). Many interventions have been proposed, with varying degrees of success, to improve balance in older people (Bieryla and Dold 2013).

6.3.2 Cognitive Abilities

A number of dimensions link cognition and aging. According to Brickman and Stern (2009), aging increases a person's chances of developing a neurodegenerative disease such as Alzheimer's disease. Cognitive deficits associated with age have been identified in working memory (Bopp and Verhaeghen 2005), reasoning (Schaie 1996), and episodic memory (Salthouse 1996). Other research highlights dementia, which is a severe loss of memory, attention, language, and problem-solving ability (Bishop et al. 2010; Salthouse 2009), and identifies less serious deficiencies in the operation of attention, problem-solving, information processing speed, spatial orientation, and divided attention (Basak et al. 2008). Cognitive function is an important indicator of the ability of older adults to maintain their independence, engagement, and health (World Health Organization 2002).

6.3.3 Social Connectedness

Social connectedness and relationships are significant influences on health-related behaviors and health outcomes (Christakis and Fowler 2007; Elwert and Christakis 2008; Stowe and Cooney 2015). For example, Christakis and Fowler (2007) found that the influence of social networks extends up to three degrees (i.e., friends, friends of friends), and certain health conditions are more influenced by friends than by closer relationships, including spouses. Gorin et al. (2008) showed that when one partner is enrolled in a weight reduction program, the likelihood of weight loss also increases for the non-registered partner. Putnam (2000) found that people who have

close social networks experience lower rates of sadness, loneliness, low self-esteem, sleeping problems, eating problems, and likelihood of death.

Social isolation is a lack of social connectedness or the objective state of having minimal contact with others (Wenger et al. 1996). Social isolation is associated with health because isolation can be caused by mental disorders, distress, or poor health (Ellis and Hickie 2001) and can lead to loneliness, sadness, and boredom (Grenade and Boldy 2008). Loneliness (defined as distress about the quality of one's social relationships) is related to numerous psychosocial risk factors including increased blood pressure, depression, impaired mental function, nursing home admission, and mortality (Hawkley et al. 2010).

6.3.4 Psychological Well-Being

Overall psychological well-being is linked to physical and cognitive health and social connectedness. Depression, poor coping skills, and a weakened sense of self-efficacy all appear to contribute to older adults' dependence, development of disease, and early mortality (World Health Organization 2002). The complex phenomenon of well-being for older adults has both objective and subjective aspects (Jeste et al. 2010). Psychological health is crucial for older adults' quality of life, and aspects such as optimism, sense of purpose, and positive attitudes are linked to longer life spans (Jeste et al. 2010; Maier and Smith 1999). However, it is important to note that subjective well-being is not synonymous with objective health but is, instead, a reflection of a person's inner satisfaction with their life situation (Stowe and Cooney 2015, citing Havighurst 1963).

6.4 Benefits of Digital Games for Older Adults

Digital games are becoming accepted as tools for improving health, and research is providing increasing evidence of their effectiveness, although reviewers have questioned the quality and consistency of many studies (Bleakley et al. 2015; Primack et al. 2012). Primack et al., in a review of the literature up to 2010, found evidence from randomized controlled trials for positive outcomes of digital game applications to physical therapy, psychological therapy, physical activity, health education, pain distraction, and disease self-management. Eight of the 38 studies that the authors reviewed targeted adults aged 50–80. Bleakley et al. reviewed literature up to 2011 for the effects of exergames on adults older than 65 years and found some evidence for a range of physical and cognitive benefits.

Although this book focuses on mobile eHealth, our review has not been limited to mobile applications because research on these specifically for older adults is new and limited and tends to address design issues rather than evidence of effectiveness. However, mobile devices, tablets in particular, are often recommended for older

adults due to their simpler interfaces, and migration to mobile devices of the types of applications described here will naturally happen over the next few years. Therefore, these examples are good indicators of the future direction of mobile, game-based eHealth for older adults.

6.4.1 Physical Benefits

"Exergames," which are video games that combine play with significant physical exercise using physical input devices (e.g., Nintendo Wii, Microsoft Xbox 360 Kinect), have been suggested as an innovative approach to improve physical activity among older adults (Larsen et al. 2013). Exergames rely on motion tracking to translate players' physical actions into game actions (e.g., bowling, dancing) and scores on a screen. Exergames' popularity has grown rapidly within the older adult population (Maillot et al. 2012). The health benefits of exergames have been widely researched. Larsen et al. (2013) analyzed four electronic databases on exergames and found positive effects of exergaming on older adults' physical health, although they could not easily compare the studies due to methodology variations.

Wiemeyer and Kliem (2012) surveyed the scientific literature on the impact of "serious" exergames aimed at disease prevention, injury prevention, and rehabilitation for older adults. They found at least partial support for using these games to improve energy expenditure, strength, basic motor control, and various nonphysical measures of well-being. The games also increased patients' motivation to adhere to their recommended chronic disease treatments over time.

In a randomized controlled experiment comparing no exercise, seated exercise, and Wii Fit gameplay for systematic Progressive Functional Rehabilitation (PFR), Daniel (2012) examined the effectiveness of 15-week interventions on indices of physical frailty among 19 older adults. Their Wii Fit group showed improved physical function and strength equivalent to the seated-exercise group, and the Wii Fit group showed higher caloric consumption relative to the other groups. Daniel concluded that a physical activity program based on exergames offers advantages over seated-exercise programs and is an option for older adults with limited access to organized exercise programs. Additionally, she noted that Wii games are varied and interactive, providing older adults at home with a wider variety of exercises than the standard exercise protocol.

Three other Wii Fit studies add to positive results for exergames. Singh et al. (2013) measured improvements for 36 elderly Malaysian women in flexibility, balance, and functional mobility, comparing six-week-long therapeutic balance exercise group to a digital gaming group using the Nintendo Wii Balance Board. They found that the older women who regularly played with the Wii improved on all three measures identically to the comparison group. Jorgensen et al. (2013) found that biofeedback-basic Nintendo Wii training resulted in significantly higher maximal voluntary contraction strength and high motivation, compared to a control group, among the 58 participants who completed the trial. Similarly, Bieryla and Dold

(2013) conducted an experiment with 12 healthy older adults and found that their Wii Fit experimental group significantly increased their BBS measure of balance after one month of training, compared to the normal activity control group. However, 3 other tests showed no significant changes.

Kinect exergames are a key part of a system developed by Gschwind et al. (2015) (www.istoppfalls.eu) to deliver an unsupervised exercise program to older adults at home. Results from their international multicenter randomized controlled trial, which included 153 participants aged 65-plus years, show that use of the application led to significant reductions in measures of physiological fall risk and postural sway, along with improved stepping reaction time. The authors conclude that more work is needed to optimize adherence to the program.

Taken together, these studies confirm that exergame-based training can lead to improvements in physical strength and balance, as measured by certain types of tests, even if additional research must be conducted to understand how. Strength and balance are crucial for maintaining daily function and preventing debilitating falls in older adults (World Health Organization 2016). However, the games in these studies are far from mobile in that they require a dedicated game machine anchored to a single location.

Moving to an exergame only available on mobile device, Kerwin et al. (2012) developed the mobile game prototype *Dance! Don't Fall* to encourage physical activity and monitor gait and fall risk in older adults. Based on a smartphone sensor worn against a player's lower back that communicates with a video display, the game teaches a single-person dance routine and gives feedback on a player's performance. Although Kerwin et al. have not done a controlled evaluation, their initial user evaluation results for the game were positive, and the project has expanded into a larger "Active@Home" fall prevention initiative (Fraunhofer Portugal 2016).

Konstitinidis et al. (2015) point to another form exergaming on mobile devices, citing examples of GPS-based mobile apps with city visualizations to encourage players to walk, run, or exercise outdoors. The commercial game *Pokemon Go* (http://pokemongolive.com/en/) adds to this approach by augmenting reality to include virtual creatures to track and capture. These examples rely on increasingly powerful web-based game engines. Although they are not so far aimed at older adults, it is not hard to imagine physical games and activities directed by mobile devices designed especially for this group to maintain and improve physical health and fitness.

6.4.2 Cognitive Benefits

As with physical benefits, the cognitive effects of digital games for older adults have been widely studied. A survey by Kaufman et al. (2016b) of 463 older Canadian adults found that mental exercise, fun, and several specific cognitive improvements (attentional focus, memory, reaction speed, problem-solving, and reasoning) were the most frequently self-reported benefits experienced from digital gameplay.

Several types of games, including some not specifically designed for cognitive training, have been shown to enhance cognitive function, although evidence is inconsistent due to variations in study methodologies (Zhang and Kaufman 2016b).

Traditional Digital Games In an early controlled experiment, Goldstein et al. (1997) studied the effects of video games like *Tetris* on older adults' reaction time, visual/cognitive adaptability, and emotional well-being. After 25 h of gameplay, the authors found a significant improvement for the experimental group in reaction time as well as a weak increase in emotional well-being; however, no difference was found in post-gameplay visual/cognitive adaptability between the two groups. Goldstein et al. warned that the relative increase in well-being could have been associated with other experimental factors such as the presence of the attendant, weekly visits, or voluntary participation in the study.

Belchior et al. (2013) examined the comparative effect of four types of training on useful field of view (UFOV) performance (processing speed, divided attention, and selective attention) for 58 older adults. Experimental groups played *Medal of Honor* or *Tetris* or had clinically validated UFOV training over 2–3 weeks. The three experimental groups all increased their visual performance significantly over the control group. The *Tetris* group also increased selective visual attention among the older adults, which was not the case for the same experiment with young adults (Green and Bavelier 2003). The authors interpreted this result to suggest that the *Tetris* game challenged their cognitive, perceptual, and motor skills more than it would have for young adults who are already familiar with digital games.

Using a game that required visualizing movement in three dimensions, Whitlock et al. (2012) studied improvements in 39 older adults' of multitasking, reasoning, and spatial memory during 2 weeks of 1-h play sessions with *World of Warcraft*, in which they completed specific challenges. They found improvements in attention control, orientation and mental rotation, recognition memory, and reasoning, and those with weaker computer skills benefited most from the game.

The games *Tetris* and *Medal of Honor* are available in mobile versions, suggesting that the cognitive benefits identified in these experiments could also be achieved on smartphones or tablets once usability issues are addressed that might deter older adults from playing on these devices.

Brain-Training Games Various games have been widely marketed and tested as tools for maintaining cognitive capacities such as memory, focus, and processing speed, with mixed results. In a significant study, Wolinsky et al. (2013) found that healthy adults over age 50 improved their concentration, speed, and agility in task switching after training for an average of 9.2 h with the game *Road Tour*, as compared to solving crossword puzzles. In Japan, Nouchi et al. (2012) examined the positive effects of the use of brain-training games on 32 older adults in Japan who played *Brain Age* or *Tetris* at home on a Nintendo DSi game console for 15 min per day, 5 days per week for 4 weeks. Effects of playing *Brain Age* were higher than those for *Tetris* for all measures of executive function and for two measures of processing speed.

Using an electrophysical test after 20 1-h training sessions with the commercial brain-training game *Lumosity*, Mayas et al. (2014) found significantly reduced distraction and increased alertness in their experimental group of healthy older adults with no previous video game experience, compared to their control group.

However, some results have been less conclusive. Miller et al. (2013) found only a gain in delayed memory function, but not in immediate memory or language, in 133 dementia-free older participants that used a computerized brain-training program for 20 min per day, 5 days per week for 2–6 months. Ballesteros et al. (2015) found that after playing brain-training games (*Speed Mach*, *Memory Matrix*, and others) for 3 months, there were significant improvements in their experimental group's attention, processing speed, memory, and subjective well-being, but the cognitive improvements disappeared after 3 months without play. Finally, Boot et al. (2013) found no significant improvements in cognitive abilities for groups playing *Brain Age 2* or *Mario Kart DS2* for 1 h per day, 5 days per week for 12 weeks, compared to their control group.

In a comprehensive study, Simons et al. (2016) reviewed all available research and company evidence about brain-training applications that use cognitive training or games to enhance performance on other tasks. They concluded that many studies have shown benefits of training on closely related tasks, but few studies have provided evidence for transfer from one cognitive domain to another. None of the studies in this review provided compelling evidence consistent with broad-based, real-world cognitive benefits from brain-training interventions. The reviewers judged this difference between hypothesized benefits and results to be due to methodological weaknesses, since few of the studies conformed to best practices for the design and reporting of intervention research.

Mobile brain-training games (apps) are widely available; for example, see Dredge (2016). Dredge points out that evidence about their effectiveness is indeed questionable and that at least one company has been fined for unproven advertising claims. He does note, however, that these games can be entertaining and appealing to older adults.

Experimental Games In addition to commercial brain-training games, some researchers have developed their own games to measure specific effects on older adults' health. ELDERGAMES (Gamberini et al. 2006, 2009) and HERMES (Buiza et al. 2009) have used custom-built games for older adults' cognitive training, although they have not provided evidence of their effectiveness. The SAVIE group at Téléuniversité, Université du Québec, has a long history of developing "frame games" for playfully delivering learning content; several of their games have been redesigned to meet older adults' usability needs and are now being converted to tablet format (Kaufman et al. 2016b; Sauvé et al. 2015; Seah 2015).

Zviel-Girshin et al. (2011) built a gaming platform specifically designed for older adults, the *Play System for Elderly Therapy (PSET)*, containing several games and diagnostic tests. The system could diagnose and treat cognitive problems by allowing the patient or the therapist to select a specific game, a program of tests, or treatments. Evaluation results showed that patients who used the system had fun

supplementing their therapy sessions. Therapists, for their part, appreciated the opportunity to work with several patients simultaneously. Although no specific results were reported in terms of cognition, the project enhanced work on the therapeutic process.

To support a set of studies, Anguera et al. (2013) developed the three-dimensional game *NeuroRacer*, with challenge levels customized to individual players' abilities. It was used to test whether older adults' multitasking performance could be improved through training. First, using the game with a sample of 20–79-year-olds, they found that multitasking performance declines linearly with age. Second, they tested the impact of the game on adults aged 60–85. After playing for 1 h, three times per week for a month, tests showed that the multitasking group had significant reduction in multitasking costs compared to the single-task and control groups. In addition, electroencephalography tests showed that they had returned their key neural indicators of cognitive control to levels normally seen in 20-year-olds, and these gains persisted for 6 months after training. The authors concluded that these results provide evidence that a custom-designed video game can be used to assess and improve cognitive ability and its underlying neural mechanisms throughout life.

In a project aimed at cognitive diagnosis and monitoring, a team from two Canadian universities has produced a tablet-based *Whack-a-Mole* game to remotely monitor inhibition and processing speed for patients with moderate dementia (Guana 2016). This combines mobile monitoring technology with a game that is simple and familiar to older adults.

Physical Games Exergames have been shown to produce cognitive, as well as physical, benefits for older adults. Maillot et al. (2012) found that a 12-week Wii-based physical training program for sedentary older adults, using a variety of games that challenged different physical and cognitive abilities, significantly improved game performance, physical function, executive control, and processing speed compared to the control group. The players did not, however, improve their visuospatial functions.

Avoiding cognitive decline allows older adults to continue to function effectively in everyday life and to safely carry on activities that they enjoy. There is at least some evidence that conventional digital games, brain-training games, experimental digital games, and exergames can all enhance older adults' cognitive function, and many of these are now or will be available on mobile devices, contributing to the health of the aging population.

6.4.3 Social Benefits

Digital games can also offer older adults benefits in terms of social contact and support. Because it is more difficult to carry out controlled experiments to confirm these benefits, researchers have tended to rely on qualitative research and observation. For example, McLaughlin et al. (2012), using focus groups and qualitative

analysis of players' comments while playing an exergame, found that these games are increasingly social activities for older adults. In an experiment using exergames with older women, Wollersheim et al. (2010) studied both the physical and psychosocial aspects of gameplay for 11 older women who played *Wii Sports* games twice per week for 6 weeks.

Interviews highlighted that the participants were forced out of their comfort zones by the game. The game also challenged their perceptions of themselves; before playing, they saw themselves as old and disconnected from the world, but after the experiment they felt younger and less disconnected. They also self-reported improved physical and social well-being and deeper social connections and shared experiences with younger family members. The authors concluded that the digital game helped to break players' isolation and decreased their feelings of loneliness. However, they cautioned that their gameplay environment, with regular technical support from researchers and constant verbal encouragement for the players, could not be generalized to independent home gameplay.

Theng et al. (2012) studied the use of Wii-based exergames for enhancing attitudes of younger and older generations toward each other. For this study, 14 teams of older adults paired with 17- or 18-year-olds participated in 6 recorded game sessions, with data gathered through pre- and post-surveys and post-gameplay individual interviews. Their results showed that the gameplay had positive results for participants' social activity, intergenerational social ties, and attitudes toward other generations, although design issues limited the games that the older adults could comfortably play.

In a controlled experiment, Chen et al. (2012) examined the benefits from the use of Xbox 360 Kinect SVG exergames on the physical and mental health of institutionalized older adults with disabilities. Sixty-one participants were divided into an experimental group, who played for three 30-min sessions per week for 4 weeks, and a control group that continued regular activities. Study results found that social functioning showed a significant increase after the experiment. However, there were no significant differences between groups in vitality, general mental health, or role limitations due to emotional problems.

In another study, Mubin et al. (2008) developed an interactive mobile social game, *Walk 2 Win*, incorporating older adult feedback gathered throughout the game's design, construction, and testing. *Walk 2 Win* is a memory game that can be played individually or in teams using smartphones. Evaluation results for both types of play, by eight older adults in 2-h sessions, showed that older people are eager to play simple games with simple rules but are not confident in their skills for playing fast games. On the social level, the study participants expressed a strong preference for more social team play, especially with their grandchildren.

Al Mahmud et al. (2010), testing their tabletop card-guessing game with older adults at a community center, concluded that the rules of the game greatly influenced social interaction among players. They recommended that game rules encourage cooperation among team members and social interaction with members of other teams. They also found that the older adults in their study appreciated opportunities to play with younger family members.

Schell et al. (2016) found that for 73 players, levels of social connectedness increased significantly, and loneliness decreased significantly, after playing in a team-based *Wii Bowling* tournament for eight weeks. Qualitative evidence from this study described how players built new friendships and continued new social interactions after the tournament. Schell et al. concluded that digital games are an enjoyable leisure activity that can help older adults to maintain and enhance their social contacts, offsetting possible increased isolation as they grow older.

Combining social interaction and health-related learning, Seah (2015) found that social interaction while playing an online *Bingo* game significantly improved 50 older adults' self-reported social connectedness. In this game, older adults were also able to learn about healthy living and nutrition through questions and answers built into the game. The combination of social interaction and learning was highly valued by subject participants.

Games played online or on social networks link players to enable socializing along with gameplay (Kirman et al. 2011). In one example, Cornejo et al. (2012) found that an older adult and her relatives who tested a Facebook-based social digital game for 5 weeks were enthusiastic about its potential to reduce loneliness and increased social interaction with their family networks during and after the research project.

Massively multiplayer online role-playing games (MMORPGs) such as *World of Warcraft* (*WoW*) offer immersive worlds that are based on social interaction with other players in persistent, online virtual environments. In a questionnaire-based study of older adult *WoW* players, Zhang and Kaufman (2015) found a link between enjoyment of relationships within the game and the development of online bridging and bonding social capital that built and sustained their social networks. Zhang and Kaufman (2016c) reported that playing MMORPGs offered older adults ways to nurture off-line relationships with family and real-life friends and to construct new meaningful and supportive relationships with friends in the game. Zhang and Kaufman (2016a) highlighted the importance of intergenerational digital gameplay for forming stronger relationships and more favorable opinions across younger and older generations.

These studies illustrate the social benefits of digital games usually played on computers or game consoles. Some of these are now, or will soon be, available on mobile devices; for example, the *Bingo* game cited above is being rewritten as a tablet application to make it more easily accessible to older adults, and Facebook games are readily available online through smartphones and tablets. By supporting social interaction and social networks for older adults, these digital games promise to help to increase their enjoyment of leisure time, sustain relationships that mean so much for their quality of life, and so contribute to their health and well-being.

6.4.4 *Benefits for Psychological Well-Being*

Psychological well-being encompasses mental and emotional health and subjectively perceived well-being. Several types of games have been shown to contribute to these.

Exergames Wiemeyer and Kliem (2012) reviewed exergames for health using Mueller et al.'s (2011) framework, which emphasized positive effects on psychological, behavioral, and social health in addition to physical condition. Wiemeyer and Kliem's conclusions highlighted exergames' positive effects on intrinsic motivation, attitude, self-control, and self-efficacy.

In another study of exergames, Rosenberg et al. (2010) assessed the feasibility, acceptability, and short-term effects of Nintendo *Wii Sports* exergames practiced by 19 American older adults with subsyndromal depression. Their results after 12 weeks of play showed significant improvements in depressive symptoms, mental health, and cognitive functioning, as well as the absence of major side effects, although there were no significant changes in physical health or anxiety. They concluded that these games are likely to be a new way to improve symptoms of older adults with subsyndromal depression.

Participants in the Wollersheim et al. (2010) study reported that, in addition to improved physical and social well-being, they experienced a sense of empowerment and improved psychological well-being as they learned to play the games despite physical frailty and shared new social experiences and connections.

Advergames Digital "advergames" – a "persuasive technology" designed to change attitudes or behaviors (Fogg 2003, p. 1) – are widely used in health promotion. The literature is sparse to date on advergames aimed specifically at older adults, but there is evidence that they are effective across a range of age groups (DeSmet et al. 2014). Lieberman's (2001) experiments with advergames for children found that they positively affected self-esteem, self-efficacy, knowledge and competence, communication, and social media; although this study was not directed at older adults, it confirms Wiemeyer and Kliem's argument that games are likely to have a role to play in maintaining and enhancing older adults' motivation and emotional health.

Brown-Johnson et al. (2015) demonstrated the power of an iPad-based learning game, *mHealth TLC*, to improve patient-physician communication using virtual clinical visits. Although they were concerned about its emotionally charged content, eight users rated the game engaging, believable, clinically appropriate, and helpful for supporting lung cancer patients, its target audience. While this game was not aimed at older adults, the study suggests that learning through mobile games may have the potential to positively affect older adults' medical communication and care.

Other Games Beyond advergames, various studies have analyzed the impact of games on emotional health when they are primarily intended for other purposes. Boot et al. (2013) and Chen et al. (2012) found no significant impact on emotional

well-being, although both studies measured this outcome. However, Goldstein et al. (1997) noted that their participants experienced greater emotional well-being than the control group after the study, either as a result of playing *Tetris* or of being part of a game experiment. In their experiment with brain-training games, Ballesteros et al. (2015) found significant improvements in the affection and assertiveness components of self-reported well-being that remained after three months without play.

In a study focused on socio-emotional functioning, Allaire et al. (2013) surveyed overall wellness, positive emotion, negative emotion, and depression among 140 older adults divided into three groups: non-players (40%), casual gamers (25%), and regular players (35%). They found that casual and regular gamers reported significantly greater well-being than non-gamers as well as lower levels of negative emotions and, to some degree, lower levels of depression. The three groups did not show any difference in their level of positive emotions, social functioning, or self-rated health. The researchers suggest that their results might indicate that digital games serve as a source of entertainment, similar to other leisure activities, which can increase older adults' well-being and reduce depression.

The game types studied here are all moving to mobile devices, as noted earlier in this chapter. This section has shown that psychological well-being promises to be an important benefit (or side effect) of these mobile games, enhancing older adults' health and quality of life.

6.5 Health Benefits by Type of Game

Digital games in several categories, some now available on mobile devices, have been shown to benefit older adults' physical, cognitive, and social health as well as their general psychological well-being and emotional health. The benefits that have been demonstrated in research studies have varied with game characteristics, study methodologies, and outcome measures; it is difficult to generalize across studies even when they use randomized, controlled research design (Bleakley et al. 2015). Tables 6.1, 6.2, and 6.3 summarize by type of game the studies and benefits covered in this review.

Exergames (Table 6.1) have been widely studied and have produced benefits in all categories: physical, cognitive, social, and psychological. Documented results sometimes depend on the test used (e.g., for physical balance), the health profile (e.g., depression for non-symptomatic people), or rules that encourage particular types of interaction (e.g., for social games). Some exergames are available on mobile devices, while others are not. With many potential benefits, these games can reduce treatment costs while minimizing the risk for older adults of physical accidents and can support maintenance of all aspects of health discussed here. Finally, these types of games can support mobility in the present and future; for example, Daniel (2012) argues that older adults should invest in personal game consoles to support their own exergame regimes. This brings us to a view of exergames as evolving mobile tools for physical and cognitive support as well as for social connectedness (Crompton 2013).

Table 6.1 Summary of studies and outcomes: exergames

Reference	Study method	Games/articles/topics studied	Sample/study duration	Outcomes/conclusions	Limitations and notes
Physical health					
Larsen et al. (2013)	Electronic database review	Seven studies	311 older adult (OA) participants	Positive impact on *physical health* in six of seven studies	Methodological differences made comparing studies difficult
Wiemeyer and Kliem (2012)	Literature review	Serious games (SGs) for health and rehabilitation	80 references	Partial support for using SGs to improve *energy expenditure*, *strength*, *basic motor control*, and some *nonphysical measures of well-being* Increased *patient motivation* for treatment adherence	Found few good-quality studies with OAs. Need work on how to achieve long-term motivation and engagement
Daniel (2012)	Randomized controlled trial (RCT)	*Wii Fit*	19 OAs: 15 weeks, 3x/week for 45 min	*Physical function* and *strength* improvements; higher *caloric consumption* than control group	Variety of Wii games makes them attractive to older adults
Singh et al. (2013)	RCT	*Wii Balance Board*	36 older women: 6 weeks, 2x/week for 40 min	Improved *flexibility*, *balance*, *functional mobility* equivalent to control group	
Jorgensen et al. (2013)	RCT	*Wii Fit*	58 OAs: 10 weeks, 2x/week for 35 min	Higher *maximal voluntary contraction strength*, high *motivation*	
Bieryla and Dold (2013)	RCT	*Wii Fit*	12 OAs: 3 weeks, 3x/week for 30 min	Improved BBS *balance* measure	No significant change in three other balance measures

(continued)

Table 6.1 (continued)

Reference	Study method	Games/articles/topics studied	Sample/study duration	Outcomes/conclusions	Limitations and notes
Gschwind et al. (2015)	RCT	Kinect custom balance- and strength-training games	153 OAs: 16 weeks, 180 min/week	Significantly improved *physiological fall risk*, *postural sway*, *stepping reaction time*	Improvements were associated with better adherence to the training program
Kerwin et al. (2012)	User testing	*Dance! Don't Fall* mobile game	10 OAs completing 5 tasks	Positive user response with feedback on suggested improvements	Needs more variety and higher levels to engage users over time
Konstitinidis et al. (2015)	Review/position paper	GPS-based mobile games		Reviews newer technologies for mobile exergames	
Wollersheim et al. (2010)	Experimental study (ES)	*Wii Sports* games	11 older women, 6 weeks baseline period +6-week intervention period, 2x/week for mean time of 51 min	Participants perceived improved *physical well-being*	Support and encouragement from other players and researchers maintained player engagement
Cognitive health					
Maillot et al. (2012)	RCT	Cognitive effects of Wii training with Balance Board	32 OAs: 24 1-h training sessions	Significant improvements in *executive function* and *processing speed tasks*	Exergames found to be more engaging, which may partly explain improvements compared to other exercise

Social health					
McLaughlin et al. (2012)	Observation and focus group study	*Boom Blox* (Wii exergame)	13 OAs	Identification of OAs' costs and benefits associated with playing a digital game. *Social interaction* is an important benefit	Usability issues and cognitive challenges from poor game design can discourage play and negate potential benefits
Wollersheim et al. (2010)	See above	See above	See above	Deeper *social connections*, *shared experiences* with younger family members, *decreased loneliness*, *improved sense of social well-being*	
Theng et al. (2012)	ES	Wii games	14 teams of OAs and teens, playing for 6 sessions	Positive results for social *activity*, *intergenerational social ties*, *attitudes toward other generations*	Older adults' play was limited by playability issues
Chen et al. (2012)	ES with control group (CG)	Xbox Kinect games	61 institutionalized OAs with disabilities: 4 weeks, 3x/week for 30 min	Significant increase in *social functioning*	No difference in vitality, general mental health, or role limitations
Schell et al. (2016)	Mixed-methods study	*Wii bowling*	73 OAs in teams in an 8-week tournament	Significantly *increased social connectedness*, *decreased loneliness*, *new friendships*, *continuing new social interactions*	

(continued)

Table 6.1 (continued)

Reference	Study method	Games/articles/topics studied	Sample/study duration	Outcomes/conclusions	Limitations and notes
Psychological well-being					
McLaughlin et al. (2012)	See above	See above	See above	*Self-esteem*, *fun*, *positive emotions*, *learning* observed as benefits	See above
Wiemeyer and Kliem (2012)	Literature review	Serious games for health and rehabilitation	80 references	Found positive effects on *intrinsic motivation*, *attitude*, *self-control*, and *self-efficacy*	
Rosenberg et al. (2010)	ES	*Wii Sports* games	19 OAs with subsyndromal depression: 12 weeks, 3x/week for 35 min	Significant improvements in *depressive symptoms*, *mental health*, *cognitive functioning*	No major side effects. No significant changes in physical health or anxiety
Wollersheim et al. (2010)	See above	See above	See above	Improved sense of *empowerment*, *psychological well-being*	

Table 6.2 Summary of studies and outcomes: brain-training games

Reference	Study method	Games/articles/topics studied	Sample/study duration	Outcomes/conclusions	Limitations and notes
Cognitive health					
Wolinsky et al. (2013)	RCT with training groups on site or at home	*Road Tour* game	207 adults aged 65+, 413 aged 50–64: 9–13 h play	Improved *concentration*, *speed*, *task-switching agility* that held or increased at 1-year follow-up	Comparable effects for both age groups
Nouchi et al. (2012)	RCT	*Brain Age*, *Tetris*	32 OAs: 4 weeks, 5x/week for 15 min	Improved *executive function*, *processing speed* for *Brain Age* players compared to *Tetris* players	
Mayas et al. (2014)	RCT	*Lumosity*	27 OAs: 10–12 weeks, 20 × 60 min	*Reduced distraction*, *increased alertness*	
Miller et al. (2013)	ES	*Brain Fitness*	Convenience sample of 69 OAs: 5x/week, 20–25 min. Evaluated at 2 and 6 months	*Improved delayed memory function*. No improvements in immediate memory or language	Those who played at least 40 sessions over 6 months improved in all 3 domains
Ballesteros et al. (2015)	RCT	*Speed Mach*, *Memory Matrix*, others	30 OAs: 10–12 weeks, 20 × 1 h play sessions	*Improved attention*, *processing speed*, *memory*	Cognitive improvements disappeared after 3 months without play
Boot et al. (2013)	RCT	*Brain Age 2*, *Mario Kart DS2*	62 OAs: 12 weeks, 5x/week for 1 h	No improvements in cognitive abilities	Action game viewed as less enjoyable

(continued)

Table 6.2 (continued)

Reference	Study method	Games/articles/topics studied	Sample/study duration	Outcomes/conclusions	Limitations and notes
Simons et al. (2016)	Literature and company information review	Brain-training tasks and games	Info on games and training programs for cognitive improvement	Found extensive evidence of improvements in *train task performance*. Less or no evidence that improvements transfer to related or non-related tasks	Found significant deficiencies in study design and implementation. Recommends best practices for evaluating brain-training claims
Psychological well-being					
Ballesteros et al. (2015)	See above	See above	See above	Increases in the *affection and assertiveness component subjective well-being* that persisted after 3 months without play	

Table 6.3 Summary of studies and outcomes: traditional digital games

Reference	Study method	Games/articles/topics studied	Sample/study duration	Outcomes/conclusions	Limitations and notes
Cognitive health					
Kaufman et al. (2016b)	Survey	Perceived benefits from digital gameplay in general	463 OAs	*Mental exercise*, *perceived improvements in attentional focus*, *memory*, *reaction speed*, *problem-solving*, *reasoning*	
Zhang and Kaufman (2016b)	Systematic literature review	Cognitive impacts of digital gameplay in general, including exergames	26 studies on OAs	Some evidence that games can *mitigate cognitive decline*	Few rigorous studies found; inconsistent evidence due to methodology variations
Goldstein et al. (1997)	RCT	*Super Tetris*	22 OAs: 5 weeks for 5 + h/week	Significant improvement in *reaction time*	No significant improvement in cognitive/perceptual agility as measured by the Stroop Color and Word Test
Belchior et al. (2013)	RCT	*Medal of Honor*, *Tetris*	58 OAs: 2–3 weeks, 6 × 90 min	Improved *visual performance* (unified field of view), *selective visual attention*	
Whitlock et al. (2012)	ES	*World of Warcraft*	39 OAs: 2 weeks, 14 h	Improved *attention control*, *orientation and mental rotation*, *recognition memory*, *reasoning*	Greater benefit for those with weaker computer skills
Psychological well-being					
Goldstein et al. (1997)	See above	See above	See above	*Greater emotional well-being*	This outcome might be the result of study participation rather than from the game
Allaire et al. (2013)	Survey		140 OAs	Casual and regular gamers reported significantly greater *well-being* and *lower negative emotions and depression*	No differences in levels of positive emotions, social functioning, or self-rated health

Brain-training games (Table 6.2), which address cognitive health, have also been widely researched and are widely available on mobile devices. However, many study outcomes have been limited to capabilities targeted in the gameplay, and there is only limited evidence for transfer from brain-training interventions to real-world outcomes. This stands in stark contrast to the marketing claims of many companies (Simons et al. 2016). Time spent training seems to be important (e.g., at least 10 h, as Seçer and Satyen (2014) suggest), and it is important to assess cognitive benefits in the long term (e.g., some seem to fade after three months, as found by Ballesteros et al. 2015). Simons et al. (2016) point out that in order to measure the utility of a brain-training game, you must consider not only the relative benefits of different interventions but also their opportunity costs; training with a game yielding 10% better performance that takes twice as long to complete might not be worthwhile. Finally, it is important to consider that these games could also have benefits in terms of entertainment and enjoyment that outweigh their opportunity costs, even if they provide no cognitive benefits.

Table 6.3 summarizes studies on traditional digital games. There is evidence that traditional non-immersive games can improve emotional well-being along with some aspects of cognitive health, and there are indications that games with immersive environments, such as *Medal of Honor* and *World of Warcraft*, provide benefits related to cognitive and visual processing. However, today, immersive environments remain more difficult to use on mobile devices because of their size and power limitations.

Various digital games built as research projects (Table 6.4) have been shown to be effective in improving aspects of cognitive and social health. It is particularly interesting that two mobile experimental games, *Whack-A-Mole (WOW)* and the exergame *Dance! Don't Fall*, have incorporated monitoring of physical or cognitive functions, blurring the line between games and the growing group of mobile applications designed to collect data and provide health feedback to individuals and their physicians. The *Play System for Elderly Therapy (PSET)* game continues this approach by providing a playful system for facilitating the therapeutic relationship.

As online digital games (Table 6.4) increasingly become venues for socializing, either through group play or through online communities, evidence is mounting for their contributions to older adults' social health, although randomized controlled trials are limited in this area. Specific benefits, usually self-reported, include increased social interaction, reduced loneliness, feelings of social connection, general psychological well-being, and others including motivation for learning when a game includes learning content. Intergenerational exchange is often cited as a benefit for these types of games.

In addition, there is some evidence for psychological benefits arising from advergames (Table 6.4), when they improve health-related knowledge, attitudes, and/or behaviors. Researchers have also suggested that digital games in general might enhance older adults' feelings of well-being by providing new entertainment and leisure activity choices (De Schutter and Brown 2016).

Table 6.4 Summary of studies and outcomes: experimental games, online social games, and advergames

Reference	Study method	Games/articles/topics studied	Sample/study duration	Outcomes/conclusions	Limitations and notes
EXPERIMENTAL GAMES					
Cognitive health					
Gamberini et al. (2006, 2009)	Prototype development, user testing	ELDERGAMES project	107 OAs: 12 weeks of testing	Prototype measures cognitive function accurately compared to accepted scales. No cognitive improvement evaluation	
Buiza et al. (2009)	Prototype development, user testing	HERMES project	Usability testing	Usability evaluation only	
Sauvé et al. (2015); Seah (2015)	Game descriptions and user evaluations	SAVIE learning games (*Live Well, Live Healthy!*, *Bingo*, others)	Various user evaluations of PC and table-based prototypes	Ergonomic evaluations; positive user feedback about *learning experiences*	
Zviel-Girshin et al. (2011)	System description	*Play System for Elderly Therapy (PSET)*	Patient and therapist evaluations	Patients enjoyed supplementing therapy sessions. Allowed therapists to work more effectively with multiple patients	
Anguera et al. (2013)	RCT	*NeuroRacer*	174 participants aged 20–79 OAs trained for 1 h 3x/week for 1 month	Multitasking group had significant *reduction in multitasking costs* compared to the single-task and control groups. *Key neural indicators returned to 20-year-old levels* and remained after 6 months	

(continued)

Table 6.4 (continued)

Reference	Study method	Games/articles/topics studied	Sample/study duration	Outcomes/conclusions	Limitations and notes
Guana (2016)	Game prototype	Mobile *Whack-A-Mole* dementia-monitoring game	Prototype demonstration	Designed to facilitate *monitoring progress of cognitive functions*	
Social health					
Mubin et al. (2008)	Game prototype	*Walk 2 Win* mobile social memory game	Eight OAs playing in 2-hour sessions either alone or in teams	Participants had strong *preference for team play, especially with grandchildren*	Players preferred simple games and were not confident about their abilities for fast-paced play
Al Mahmud et al. (2010)	Game prototype	Tabletop card-guessing game	User testing	Rules of game influenced cooperation and social interaction; OAs *appreciated play with younger family members*	
ONLINE SOCIAL GAMES					
Social health					
Cornejo et al. (2012)	User test	*GuessMyCaption*	One OA, 12 relatives for 5-week test	*Increased social interaction within family*. Participants were positive about the game's potential to increase social connections online and off-line	

Zhang and Kaufman (2015)	Online survey	*World of Warcraft*	222 OAs	*Enjoyment of online relationships was associated with greater bridging and bonding social capital* for stronger social networks	
Zhang and Kaufman (2016c)	Online survey	*World of Warcraft*	176 OAs	Playing offered older adults ways to *nurture off-line relationships with family and real-life friends* and to *construct new meaningful and supportive relationships with friends* in the game	
Zhang and Kaufman (2016a)	Literature review	Digital games, intergenerational play	19 studies	Intergenerational digital gameplay facilitates *forming stronger relationships and more favorable opinions across younger and older generations*	
ADVERGAMES					
Social health					
Seah (2015)	Mixed-method study	Multiplayer *Bingo* learning game about nutrition and health	50 older adults playing for 30–45 min twice per week for 4 weeks	Significantly increased self-reported social connectedness; new learning about nutrition and about computers	
Psychological well-being					
Brown-Johnson et al. (2015)	User test	*mHealth TLC* iPad health game prototype	Eight health professionals (not older adults)	The game was rated as engaging, believable, clinically appropriate, and helpful for supporting lung cancer patients	mhealth game example; did not involve older adults

In terms of mHealth, mobile digital games provide a huge opportunity to increase digital health management. This chapter has noted some early mobile games that link older adult play with diagnostic data collection to detect or monitor health conditions. Older adults continue to enjoy, and find benefits from, playing commercial digital games alone and with family and friends. Finally, the development of specific mHealth games for older adults continues. All of these point to a future in which older adults can enjoy mobile games while managing and monitoring physical abilities and cognitive skills, supporting and developing their social networks, and maintaining their general well-being and quality of life.

6.6 Limitations and Conclusions

There are several limitations to the work presented here. First, it is difficult to untangle the heterogeneity of protocols used in digital game research. For example, several variables that may be important, such as age or differences in the types of digital games, were not fully considered in the reviewed studies. Limitations also lie in the isolation of variables: in fact, in the experiments the researchers clearly separate types of digital games, sometimes comparing them. They often separate the effects in the psychological tradition, e.g., cognition, emotion, and socialization. Several studies dissociate variables when they are often linked, for example, Wollersheim et al. (2010), who mention the social support of the game experience or the novelty of the game as confounding the results. As has been pointed out by other reviewers, therefore, differences in experimental protocols make it impossible to rigorously summarize and compare experimental results.

We suggest several areas for further research. The most important one relates to the theme of this article, i.e., the gameplay process and outcomes of mobile digital games. Also, studies on the duration of any benefits found would be useful. Many authors mention the need for work concerning the adaptation of successful digital games to the needs and capabilities of older adults. Whitlock et al. (2012) showed that the participants' backgrounds and gameplay expertise have major impacts on realized benefits; therefore, more research should be conducted on individual differences in older adult players. Miller et al. (2013) also mention that for cognitive outcomes, slight individual deficiencies can vary the results. All these results show the complexity and tremendous diversity inherent in older adults in any digital game context and research protocol. It is important for researchers to work closely with participants in the design and implementation of research studies and to employ a situational epistemology that promotes health and successful aging.

Acknowledgments This research was supported by AGE-WELL NCE Inc., a member of Canada's Networks of Centres of Excellence program.

References

Agarwal S, Lau CT (2010) Remote health monitoring using mobile phones and web services. Telemed e-Health 16(5):603–607

Al Mahmud A, Mubin O, Shahid S, Martens J-B (2010) Designing social games for children and older adults: two related case studies. Entertainment Comput 1(3–4):147–156. doi:10.1016/j.entcom.2010.09.001

Allaire JC, McLaughlin AC, Trujillo A, Whitlock LA, Laporte L, Gandy M (2013) Successful aging through digital games: Socioemotional differences between older adult gamers and non-gamers. Comput Hum Behav 29(4):1302–1306. doi:10.1016/j.chb.2013.01.014

Alvarez RC (2002) The promise of e-health – a Canadian perspective. eHealth Int 1(1):4

Anderson M (2015) Technology device ownership: 2015. Pew Research Center, Washington, DC. Retrieved from http://www.pewinternet.org/2015/10/29/the-demographics-of-device-ownership/

Anguera JA, Boccanfuso J, Rintoul JL, Al-Hashimi O, Faraji F, Janowich J et al (2013) Video game training enhances cognitive control in older adults. Nature 501(7465):97–101. doi:10.1038/nature12486

Baldwin S, Hsu Y-C, Ching Y-H (2015) Mobile apps for older adults: health, learning, and living. In *Proceedings, E-learn 2015: world conference on E-learning in corporate, government, healthcare, and higher education 2015*. ACM, New York, pp 1402–1407

Ballesteros S, Mayas J, Prieto A, Toril P, Pita C, Ponce de Leon L et al (2015) A randomized controlled trial of brain training with non-action video games in older adults: results of the 3-month follow-up. Front Aging Neurosci 7:45. doi:10.3389/fnagi.2015.00045

Basak C, Boot WR, Voss MW, Kramer AF (2008) Can training in a real-time strategy video game attenuate cognitive decline in older adults? Psychol Aging 23(4):765–777. doi:10.1037/a0013494

Belchior P, Marsiske M, Sisco SM, Yam A, Bavelier D, Ball K, Mann P (2013) Video game training to improve selective visual attention in older adults. Comput Hum Behav 29(4):1318–1324. doi:10.1016/j.chb.2013.01.034

Bieryla KA, Dold NM (2013) Feasibility of Wii fit training to improve clinical measures of balance in older adults. Clin Interv Aging 8:775–781. doi:10.2147/CIA.S46164

Bishop NA, Lu T, Yankner BA (2010) Neural mechanisms of ageing and cognitive decline. Nature 464:529–535. doi:10.1038/nature08983

Bland CJ, Meurer LN, Maldonado GA (1995) A systematic approach to conducting a non-statistical meta-analysis of research literature. Acad Med 70(7):642–653

Bleakley CM, Charles D, Porter-Armstrong A, McNeill MDJ, McDonough S, McCormack B (2015) Gaming for health: a systematic review of the physical and cognitive effects of interactive computer games in older adults. J Appl Gerontol 34(3):NP166–NP189. doi:10.1177/0733464812470747

Boot WR, Champion M, Blakely DP, Wright T, Souders DJ, Charness N (2013) Video games as a means to reduce age-related cognitive decline: attitudes, compliance, and effectiveness. Front Psychol 4:31. doi:10.3389/fpsyg.2013.00031

Bopp KL, Verhaeghen P (2005) Aging and verbal memory spans: a meta-analysis. J Gerontol B Psychol Sci Soc Sci 60(5):223–233. doi:10.1093/geronb/60.5.P223

Brickman AM, Stern Y (2009) Aging and memory in humans. Encycl Neurosci 1:175–180. Retrieved from http://www.cumc.columbia.edu/dept/sergievsky/pdfs/agingandmemoryinhumans.pdf

Brown-Johnson C, Berrean B, Cataldo JK (2015) Development and usability evaluation of the mHealth tool for lung cancer (mHealth TLC): a virtual world health game for lung cancer patients. Patient Educ Couns 98(4):506–511. doi:10.1016/j.pec.2014.12.006

Buiza C, Soldatos J, Petsatodis T, Geven A, Etxaniz A, Tscheligi M (2009) HERMES: pervasive computing and cognitive training for ageing well. In: Omatu S et al (eds) Distributed

computing, artificial intelligence, bioinformatics, soft computing, and ambient assisted living. Springer-Verlag, Berlin, pp 756–763
Chen S-T, Huang Y-GL, Chiang I-T (2012) Using somatosensory video games to promote quality of life for the elderly with disabilities. In: DIGITEL'12: Proceedings of the 2012 IEEE fourth international conference on digital game and intelligent toy enhanced learning. ; IEEE Computer Society, Washington, DC, pp 258–262. doi:10.1109/DIGITEL.2012.68
Christakis NA, Fowler JH (2007) The spread of obesity in a large social network over 32 years. N Engl J Med 357:370–379. doi:10.1056/NEJMsa066082
Cornejo R, Hernandez D, Favela J, Tentori M, Ochoa S (2012) Persuading older adults to socialize and exercise through ambient games. In: Proceedings, 2012 6th international conference on pervasive computing Technologies for Healthcare (PervasiveHealth) and workshops. IEEE, New York, pp 215–218
Crompton H (2013) A historical overview of mobile learning: toward learner-centered education. In: Berge ZL, Muilenberg LY (eds) Handbook of mobile learning. Routledge, New York, pp 3–14
Daniel K (2012) Wii-hab for pre-frail older adults. Rehabil Nurs 37(4):195–201. doi:10.1002/rnj.25
De Schutter B, Brown JA (2016) Digital games as a source of enjoyment in later life. Games Culture 11(1–2):28–52. doi:10.1177/1555412015594273
DeSmet A, Van Ryckeghem D, Compernolle S, Baranowski T, Thompson D, Crombez G et al (2014) A meta-analysis of serious games for health lifestyle promotion. Prev Med 69:95–107. doi:10.1016/j.ypmed.2014.08.026
Dredge S (2016 March 23) Five of the best brain-training apps. The Guardian, London. Retrieved from https://www.theguardian.com/technology/2016/mar/23/brain-training-apps-five-of-the-best
Ellis P, Hickie I (2001) What causes mental illness? In: Bloch S, Singh B (eds) Foundations of clinical psychiatry. Melbourne University Press, Melbourne, pp 43–62
Elwert F, Christakis NA (2008) Variation in the effect of widowhood on mortality by the causes of death of both spouses. Am J Public Health 98(11):2092–2098
Eysenbach G (2001) What is e-health? J Med Internet Res 3(2):e20. doi:10.2196/jmir.3.2.e20
Fausset CB, Harley L, Farmer S, Fain B (2013) Older adults' perceptions and use of technology: a novel approach. In: Stephanidis C, Atona M (eds) Universal access in human-computer interaction: user and context diversity. Springer International Publishing AG, Cham, pp 51–58
Fogg BJ (2003) Persuasive technology: using computers to change what we think and do. Morgan Kaufmann Publishers, San Francisco
Fraunhofer Portugal (2016) Active@home launched to prevent falls using traditional dances and tai chi training. Associação Fraunhofer Portugal Research, Porto. Retrieved from http://www.fraunhofer.pt/en/fraunhofer_portugal/news/news_archive/active-home-launched-to-prevent-falls-using-traditional-dances-a.html
Gamberini L, Alcaniz M, Barresi G, Fabregat M, Ibanez F, Prontu L (2006) Cognition, technology and games for the elderly: an introduction to the ELDERGAMES project. Psychnol J 4(3):285–308
Gamberini L, Martino F, Seraglia B, Spagnolli A, Fabregat M, Ibanez F et al (2009) Eldergames project: an innovative mixed-reality table-top solution to preserve cognitive functions in elderly people. In: HSI'09: proceeding of the 2nd conference on human system interactions. ACM, New York, pp 161–166
Goldstein J, Cajko L, Oosterbroek M, Michielsen M, Van Houten O, Salverda F (1997) Video games and the elderly. Soc Behav Personality 25(4):345–352
Gorin AA, Wing RR, Fava JL, Jakicic JM, Jeffery R, West DS et al (2008) Weight loss treatment influences untreated spouses and the home environment: evidence of a ripple effect. Int J Obes 32:1678–1684. doi:10.1038/ijo.2008.150
Green CS, Bavelier D (2003) Action video game modifies visual selective attention. Nature 423:534–537

Grenade L, Boldy D (2008) Social isolation and loneliness among older people: issues and future challenges in community and residential settings. Australia Health Rev 32(3):468–478

Gschwind YS, Eichberg S, Ejupi A, de Rosario H, Kroll M, Marston HR et al (2015) ICT-based system to predict and prevent falls (iStoppFalls): results from an international multicenter randomized controlled trial. Eur Rev Aging Phys Act 12(10):1–11. doi:10.1186/s11556-015-0155-6

Guana A (2016) Western Ottawa Whack-a-Mole (WOW) computer game. Demo presented at the AGE-WELL 2016 Annual conference, Montreal

Havighurst RJ (1963) Successful aging. In: Williams RH, Tibbitts C, Donahue W (eds) *Processes of aging*. Atherton Press, New York, pp 299–320

Hawkley LC, Thisted RA, Masi CM, Cacioppo JT (2010) Loneliness predicts increased blood pressure: 5-year cross-lagged analyses in middle-aged and older adults. Psychol Aging 25(1):132–141. doi:10.1037/a0017805

Human Resources and Skills Development Canada (2011) Canadians in context – Aging population. Human Resources and Skills Development Canada, Ottawa. Retrieved from: http://www4.hrsdc.gc.ca/.3ndic.1t.4r@-eng.jsp?iid=33

Hwang MY, Hong JC, Hao YW, Jong JT (2011) Elders usability, dependability, and flow experiences on embodied interactive video games. Educ Gerontol 37(8):715–731. doi:10.1080/03601271003723636

Jeste DV, Depp CA, Vahia IV (2010) Successful cognitive and emotional aging. World Psychiatry 9(2):78–84

Jorgensen MG, Laessoe U, Hendriksen C, Nielsen OBF, Aagaard P (2013) Efficacy of Nintendo Wii training on mechanical leg muscle function and postural balance in community-dwelling older adults: a randomized controlled trial. J Gerontol Ser A Biol Med Sci 68(7):845–852. doi:10.1093/gerona/gls222

Kampmeijer R, Pavlova M, Tambor M, Golinowska S, Groot W (2016) The use of e-health and m-health tools in health promotion and primary prevention among older adults: a systematic literature review. BMC Health Serv Res 16(Suppl 5):467–479. doi:10.1186/s12913-016-1522-3

Kaufman D, Munteanu C, Moffatt K. (2016a) WP4-TECH-APPS: technology for active participation in society. In: Research summary presented at the AGE-WELL 2016 Annual conference, Montreal

Kaufman D, Sauvé L, Renaud L, Sixsmith A, Mortenson B (2016b) Digital gameplay by older adults: patterns, benefits, and challenges. Simul Gaming 47(4):475–489. doi:10.1177/1046878116645736

Kerwin M, Nunes F, Silva PA (2012) Dance! don't fall – preventing falls and promoting exercise at home. Stud Health Technol Inform 177:254–259. doi:10.3233/978-1-61499-069-7-254

Kirman B, Björk S, Deterding S, Paavilainen J, Rao V (2011) Social game studies at CHI 2011. In: Proceedings of CHI'11: extended abstracts on human factors in computing systems. ACM, New York, pp 17–20. doi:10.1145/1979742.1979590

Konstitinidis EI, Bamparopoulos G, Bamidis PD (2015) Transfering full body exergames from desktop applications to mobile devices: the role of the internet of things. In: Proceedings of IMCL2015–2015 international conference on interactive mobile communication technologies and learning. IEEE, New York, pp 254–258. doi:10.1109/IMCTL.2015.7359598

Kuyken W (1995) The World Health Organization quality of life assessment (WHOQOL): position paper from the World Health Organization. Soc Sci Med 41(10):1403–1409. doi:10.1016/0277-9536(95)00112-K

Larsen LH, Schou L, Lund HH, Langberg H (2013) The physical effect of exergames in healthy elderly – a systematic review. Games Health J 2(4):205–212. doi:10.1089/g4h.2013.0036

Lieberman DA (2001) Management of chronic pediatric diseases with interactive health games: theory and research findings. J Ambul Care Manag 24(1):26–38

Maier H, Smith J (1999) Psychological predictors of mortality in old age. J Gerontol: Psychol Sci 54:44–54

Maillot P, Perrot A, Hartley A (2012) Effects of interactive physical-activity video-game training on physical and cognitive function in older adults. Psychol Aging 27(3):589–600. doi:10.1037/a0026268

Marston HR, Freeman S, Bishop KA, Beech CL (2016) A scoping review of digital gaming research involving older adults aged 85 and older. Games Health J 5(3):157–174. doi:10.1089/g4h.2015.0087

Mayas J, Parmentier FBR, Andrés P, Ballesteros S (2014) Plasticity of attentional functions in older adults after non-action video game training: a randomized controlled trial. PLoS One 9(3):e92269. doi:10.1371/journal.pone.0092269

McLaughlin A, Gandy M, Allaire J, Whitlock L (2012) Putting fun into video games for older adults. Ergonomics Des Q Human Factors Appl 20(2):13–22. doi:10.1177/1064804611435654

Miller KJ, Dye RV, Kim J, Jennings JL, O'Toole E, Wong J, Siddarth P (2013) Effect of a computerized brain exercise program on cognitive performance in older adults. Am J Geriatr Psychiatry 21(7):655–663. doi:10.1016/j.jagp.2013.01.077

Misha K (2011) mHealth: new horizons for health through mobile technologies. Word Health Organization, Geneval. Retrieved from http://www.who.int/goe/publications/goe_mhealth_web.pdf

Mubin O, Shahid S, Al Mahmud A (2008) Walk 2 win: towards designing a mobile game for elderly's social engagement. In: BCS-HCI'08: proceedings of the 22nd British HCI group annual conference on people and computers: culture, creativity, interaction – volume 2. British Computer Society, Swinton, pp 11–14

Mueller F, Edge D, Vetere F, Gibbs MR, Agamanolis St, Bongers B, Sheridan JG (2011) Designing sports: a framework for exertion games. In: CHI'11: Proceedings of the SIGCHI conference on human factors in computing systems, Vancouver, Canada

Nouchi R, Taki Y, Takeuchi H, Hashizume H, Akitsuki Y, Shigemune Y et al (2012) Brain training game improves executive functions and processing speed in the elderly: a randomized controlled trial. PLoS One 7(1):1–9. doi:10.1371/journal.pone.0029676

Oliveira M (2014) Most Canadian seniors have mobile phones, but not "smart" ones: poll. CTV News, Toronto. Retrieved from http://www.ctvnews.ca/sci-tech/most-canadian-seniors-have-mobile-phones-but-not-smart-ones-poll-1.1648473

Perednia DA, Allen A (1995) Telemedicine technology and clinical applications. JAMA 273(6):483–488

Primack BA, Carroll MV, McNamara M, Klem ML, King B, Rich M et al (2012) Role of video games in improving health-related outcomes: a systematic review. Am J Prev Med 42(6):630–638. doi:10.1016/j.amepre.2012.02.023

Putnam RD (2000) Bowling alone: the collapse and revival of American community. Simon & Schuster, New York

Raffelini C (2005) La télémédecine entre lorganisation et la technologie [Telemedicine between the organization and technology]. Unpublished doctoral dissertation, Université du Québec à Montréal

Rosenberg D, Depp CA, Vahia IV, Reichstadt J, Palmer BW, Kerr J et al (2010) Exergames for subsyndromal depression in older adults: a pilot study of a novel intervention. Am J Geriatr Psychiatry 18(3):221–226. doi:10.1097/JGP.0b013e3181c534b5

Salthouse TA (1996) The processing-speed theory of adult age differences in cognition. Psychol Rev 103(3):403–428. doi:10.1037/0033-295X.103.3.403

Salthouse TA (2009) When does age-related cognitive decline begin? Neurobiol Aging 30(4):507–514. doi:10.1016/j.neurobiolaging.2008.09.023

Sauvé L, Renaud L, Kaufman D, Duplàa E (2015) Validation of the educational games for seniors: live well, live healthy! Procedia Soc Behav Sci 176:674–682. doi:10.1016/j.sbspro.2015.01.526

Schaie KW (1996) Intellectual development in adulthood: the Seattle longitudinal study. Cambridge University Press, Cambridge

Schell R, Hausknecht S, Zhang F, Kaufman D (2016) Social benefits of playing Wii bowling for older adults. Games Cult 11(1–2):81–103. doi:10.1177/1555412015607313

Seah ET-W (2015) Understanding the learning and social gameplay experience of older adults playing a Bingo digital game. Unpublished doctoral dissertation, Simon Fraser University, Burnaby, BC, Canada. Retrieved from http://summit.sfu.ca/item/16066

Seçer I, Satyen L (2014) Video game training and reaction time skills among older adults. Act Adapt Aging 38(3):220–236. doi:10.1080/01924788.2014.935908

Serafini M (1995) High-tech housecalls. Natl J 57:258–264

Silva BMC, Rodrigues JJPC, de la Diez T, López-Coronado M, Saleem K (2015) Mobile-health: a review of current state in 2015. J Biomed Inform 56:265–272. doi:10.1016/j.jbi.2015.06.003

Simons DJ, Boot WR, Charness N, Gathercole SE, Chabris CF, Hambrick DZ, Stine-Morrow EAL (2016) Do "brain-training" programs work? Psychol Sci Public Interest 17(3):103–186. doi:10.1177/1529100616661983

Singh DKA, Rajaratnam BS, Palaniswamy V, Raman VP, Bong PS, Pearson H (2013) Effects of balance-focused interactive games compared to therapeutic balance classes for older women. Climacteric 16(1):141–146. doi:10.3109/13697137.2012.664832

Statistics Canada (2007) Enquête canadienne sur lutilisation dinternet [Canadian investigation on the use of the internet]. Statistics Canada, Ottawa. Retrieved from: http://www.statcan.gc.ca/daily-quotidien/080612/dq080612b-fra.htm

Statistics Canada (2014) Rates of internet use, by age group, selected years. Statistics Canada, Ottawa

Statistics Canada (2015) Activity-limiting injuries, 2009. Statistics Canada, Ottawa. Retrieved from http://www.statcan.gc.ca/pub/82-625-x/2010002/article/11272-eng.htm

Stowe JD, Cooney TM (2015) Examining Rowe and Kahn's concept of successful aging: importance of taking a life course perspective. The Gerontologist 55(1):43–50. doi:10.1093/geront/gnu055

Strode SW, Gustke S, Allen A (1999) Technical and clinical progress in telemedicine. J Am Med Assoc 281(12):1066–1068

Theng Y-L, Chua PH, Pham TP (2012) Wii as entertainment and socialisation aids for mental and social health of the elderly. In: CHI EA '12: CHI'12 extended abstracts on human factors in computing systems. ACM, New York, pp 691–702. doi:10.1145/2212776.2212840

Wattanasoontorn V, Boada I, García R, Sbert M (2013) Serious games for health. Entertain Comput 4:231–247. doi:10.1016/j.entcom.2013.09.002

Wenger C, Davies R, Shahtahmasebi S, Scott A (1996) Social isolation and loneliness in old age: review and model refinement. Ageing Soc 16(3):333–358

Whitlock LA, McLaughlin AC, Allaire JC (2012) Individual differences in response to cognitive training: using a multi-modal, attentionally demanding game-based intervention for older adults. Comput Hum Behav 28(4):1091–1096. doi:10.1016/j.chb.2012.01.012

Wiemeyer J, Kliem A (2012) Serious games in prevention and rehabilitation – a new panacea for elderly people? Eur Rev Aging Phys Act 9(1):41–50. doi:10.1007/s11556-011-0093-x

Wolinsky FD, Vander Weg MW, Howren MB, Jones MP, Dotson MM (2013) A randomized controlled trial of cognitive training using a visual speed of processing intervention in middle aged and older adults. PLoS One 8(5):e61624. doi:10.1371/journal.pone.0061624

Wollersheim D, Merkes M, Shiels N, Liamputtong P, Wallis L, Reynolds F, Koh L (2010) Physical and psychosocial effects of Wii video game usage among older women. Int J Emerg Technol Soc 8(2):85–98

World Health Organization (1993) Study protocol for the World Health Organization project to develop a quality of life assessment instrument (WHOQOL). Qual Life Res 2(2):153–159

World Health Organization (2002) Active ageing: a policy framework. World Health Organization, Geneva. Retrieved from http://apps.who.int/iris/handle/10665/67215

World Health Organization (2016) Falls prevention in older age. World Health Organization, Geneva. Retrieved from http://www.who.int/ageing/projects/falls_prevention_older_age/en/

Zhang F, Kaufman D (2015) The impacts of social interactions in MMORPGs on older adults' social capital. Comput Hum Behav 51:495–503. doi:10.1016/j.chb.2015.05.034

Zhang F, Kaufman D (2016a) A review of intergenerational play for facilitating interactions and learning. Gerontechnology 14(3):127–138. doi:10.4017/gt.2016.14.3.002.00
Zhang F, Kaufman D (2016b) Cognitive benefits of older adults digital gameplay: a critical review. Gerontechnology 15(1):3–16. doi:10.4017/gt.2016.15.1.002.00
Zhang F, Kaufman D (2016c) Older adults' social interactions in MMORPGs. Games Culture 11(1–2):150–169. doi:10.1177/1555412015601757
Zviel-Girshin R, Reichman A, Abraham I, Hammer L, Shema A, Kimhi A (2011) Play system for therapy for the elderly. In: Proceedings, 2011 IEEE international conference on microwaves, communications, antennas and electronics systems (COMCAS). IEEE, New York, pp 1–5. doi:10.1109/COMCAS.2011.6105934

Emmanuel Duplàa is a professor in the Faculty of Education at the University of Ottawa, specializing in information and communication technologies (ICT) for learning. He has participated in projects on design ergonomics and planning, distance education and training in eHealth. He is currently conducting research on educational video games, digital literacy, and e-learning design processes.

David Kaufman is a professor in the Faculty of Education at Simon Fraser University, Canada. He has published extensively with more than 120 published articles and 3 books to his credit; serves as a reviewer for many journals, granting agencies and professional associations; and has received more than $3 million in funding. His current research focuses on digital technologies to support ageing well.

Louise Sauvé is a professor of Educational Technology at TÉLUQ University in Quebec City, Canada. She has worked for many years as a distance education specialist, has developed many digital games and has published extensively on games and simulations for learning.

Lise Renaud is a professor at the University of Quebec at Montreal and director of ComSanté, a research centre on communication and health. She has more than 20 years of experience doing research and conducting interventions in public health in Montreal. She has 6 books and many articles to her credit.

Alice Ireland is an educational consultant in Vancouver, BC. She was formerly an executive director of Simon Fraser University's Simulation and Advanced Gaming Technologies (SAGE) for Learning Project and an associate professor of Management Information Systems at the Dalhousie University School of Business. She is currently a work package coordinator for AGE-WELL NCE Inc.

Part IV
Ageing Perspectives to the Barriers and Enablers of Technology Use

Chapter 7
Digital Game Technology and Older Adults

Hannah R. Marston, Michael Kroll, Dennis Fink, Rakel Poveda, and Yves J. Gschwind

Abstract This chapter provides readers with an overview of digital gaming trends across Europe and Australia, using current and up-to-date statistics detailing gaming preferences, demographics and digital device usage and ownership. Providing a contemporary overview of the literature in the field of digital gaming and ageing the authors aim to demonstrate the work that has been covered by international academics. These domains include a series of reviews which have focused on health rehabilitation and gaming, eHealth, digital gaming, fall prevention and active ageing. Further discussion focuses on the use and deployment of mobile health apps and digital gaming and how they are used within the field of ageing, in regard to gamification, chronic health conditions and the nature of interaction and engagement by users. Results are presented from the iStoppFalls project, whereby an ICT survey was deployed to ascertain participants ICT usage, ownership and behaviours. The results in this chapter focus primarily on digital games, how participants learnt to play games, their preferred game genres and online gaming habits. Common challenges are explored and discussed by the authors in regards to gaming research with

H.R. Marston (✉)
Health & Wellbeing Priority Research Area, School of Health, Wellbeing & Social Care, Faculty of Wellbeing, Education & Language Studies, The Open University, Milton Keynes, Buckinghamshire, UK

Institute of Movement and Sport Gerontology, German Sport University Cologne, Cologne, Germany

Centre for Research in Computing, Open University, Milton Keynes, UK
e-mail: Hannah.Marston@open.ac.uk; marstonhannah@hotmail.com

M. Kroll • D. Fink
Institute of Movement and Sport Gerontology, German Sport University Cologne, Cologne, Germany

R. Poveda
Instituto de Biomecánica de Valencia, Universidad Politécnica de Valencia, Valencia, Spain

Biomedical Research Networking Centre in Bioengineering, Biomaterials and Nanomedicine (CIBER-BBN), Healthcare Technology Group, Valencia, Spain

Y.J. Gschwind
Neuroscience Research Australia, University of New South Wales, Barker Street, Randwick, Sydney 2031, Australia

H.R. Marston et al. (eds.), *Mobile e-Health*, Human–Computer Interaction Series,
DOI 10.1007/978-3-319-60672-9_7

recommendations proposed for future use and engagement of digital gaming, mobile health apps and wearables.

7.1 Introduction

Global ageing is a concern for researchers, governments, stakeholders and international organizations such as the World Health Organization (WHO). In 2013, the WHO reported the increase of issues associated with our ageing populations via international conferences. In the respective published report, the WHO states that ageing is an international occurrence resulting from decreased mortality and fertility. Statistics show that the overall global population aged 60+ years increased from 9.2% in 1990 to 11.7% in 2013 and will continue to grow reaching 21.1% by 2050 (WHO 2013). Thus, globally, this proportion will more than double from 841 million people in 2013 to two billion in 2050 (WHO 2013). Moreover, the rise of the oldest old (persons aged 80+ years) is expected to grow from 14% in 2013 to 19% in 2050, and the WHO noted that if this prediction is reached, it will result in 392 million people aged 80+ years by 2050.

The notion of innovative technological approaches has been undertaken by researchers in the fields of gerontology, health, digital game studies, computer science and human computer interaction (HCI) to explore how digital games, mobile health (mHealth) apps and respective software can assist our ageing populations to lead a healthy and active life. Technology can be a powerful medium to integrate into the lives and homes of our ageing populations. This chapter explores suitable solutions through various technologies which are crucial for maintaining independence, health, wellbeing and quality of life while aiming to understand the needs and requirements of older adults in relation to technological solutions such as digital games.

7.2 Ageing and Technology

The notion of ageing in place has been defined by the Centers for Disease Control and Prevention as "the ability to live in one's own home and community safely, independently, and comfortably, regardless of age, income, or ability level" (2013, https://www.cdc.gov/healthyplaces/terminology.htm). Ageing in place refers to older adults aged 65+ years preferring to stay in their own home as they age (Kochera et al. 2005; Peek et al. 2015; Satariano et al. 2014; Peek et al. 2014). Therefore, technology supporting individual's ageing in place can enable opportunities for communication and engagement through devices including: Internet searching for specific information, communicating with friends and family via email and Skype/social media outlets such as Facebook. Further, digital games can also aid ageing in place and enhance intergenerational relationships. Previous work undertaken by Voida and Greenberg (2009) and Voida et al. (2010) has shown intergenerational gaming to be a positive step forward in terms of building intergenerational

relationships through digital games. Moreover, technology used to promote safety and security of persons to age in place may include webcams, fall detectors, home monitoring and inactivity monitors.

Since 2000, there has been interest from the academic and industry communities into exploring how digital games and accompanying software could be made attractive to and used by older adults. These efforts have resulted in annual statistics, research and development as well as marketing strategies by companies which aim to broaden their gaming audiences by presenting digital gaming to older adults as well as children and young adults.

7.2.1 Digital Gaming Perspectives from America, Europe and Australia

The Entertainment Software Association (ESA 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016) and the Interactive Software Federation of Europe (ISFE 2012) in the USA and Europe have published national statistics describing digital gaming habits across different age cohorts. The average age of gamers has fluctuated per the annual statistics published by the Entertainment Software Association (ESA). To date, the average age of a gamer is 35 years (ESA 2016). It should be noted that statistics published by the ESA, ISFE (Interactive Software Federation of Europe) and IGEA (Interactive Games & Entertainment Association) have not included data relating to adults 65+ years and over. For example, the ESA has published data relating to adults aged 50+ years and above since 2004 without further differentiating age groups.

7.2.2 Europe

Digital gaming statistics published by the ISFE focus on the type of games played, purchasing habits, gender, and age, and the reasons why games are played by European citizens from the perspective of individual European member states and as an overall perspective. For the purpose of this chapter, Germany and Spain are discussed because they were member states in the European Union (EU) involved in an EU-funded project (2011–2014) called iStoppFalls project. The iStoppFalls project included a randomized controlled trial (RCT) comprised of six EU partners and one Australian partner (i.e. three intervention sites: German Sport University Cologne, Instituto Biomecanica Valencia, Neuroscience Research Australia).

Gender of European games survey (ISFE 2012) showed that 54% of gamers are male with adults aged 55–64 years representing 11% of respondents. European respondents reported online game playing to be the most popular medium (81%) while 35% of the respondents had bought a game in the past 12 months (19% new games, 8% online games, 7% second-hand games and 7% game apps).

7.2.2.1 Germany

Digital gamers (n = 5189 online and offline respondents) surveyed in Germany (ISFE, Germany 2012) showed similar results as the rest of Europe. Specific data for Germany displays online gaming to be the most popular/preferred gaming format in Germany with 79% of adults playing, 54% play with friends who they know from the real world, 34% with family/relatives, 27% with online strangers and 26% with online friends who they have not met in real life. The type of devices used to play games were a personal computer (PC, 25%), laptop/netbook (20%), smartphone (17%), Nintendo Wii (11%) and Nintendo DS (8%).

7.2.2.2 Spain

Digital gamers (n = 3035 online and offline respondents) surveyed in Spain (ISFE, Spain 2012) showed that 83% of respondents played online. Fifty-six percent played with friends who they knew from the real world, whereas 41% of respondents played online games with strangers. Additionally, 29% played with friend/relatives, and a further 29% played online games with friends they have not met in the real world. The proportion of online gaming, the weekly rate of online gaming, and the interest in technology among gamers and non-gamers were similar to German gamers. Games were played on a multitude of devices: smartphone (24%), laptop/netbook (22%), PC (21%), Nintendo DS handheld console (12%) and Nintendo Wii (15%).

7.2.3 Australia

Similarly, to the ESA and the ISFE publications of respective gamers in those member states, the IGEA (IGEA 2014) in Australia also have limited reporting of older gamers. The IGEA (2014) reported that the average age of an Australian gamer is 32 years, while 47% of respondents were female gamers and 53% of respondent's male gamers. It is unclear from the respective publication why this data has not been reported, unless there were no adults aged 60 years or over who completed the survey.

Reasons for game playing varied and included: 32% played console or PC games to have fun, 17% played to relieve boredom and pass the time away, 16% played games to relax or to relieve stress, while 12% played to keep their mind active and 6% enjoyed experiencing a challenge when gaming. Reasons to play games on a mobile or tablet device included: 32% played to relieve boredom or pass the time, 20% wanted to have fun, 15% played games on these mobile devices to relax or relieve stress, 11% played to keep their mind active, and 6% wanted games to be

challenging during their gaming experience (IGEA 2014). Playing digital games during the day or week varied, and 91% reported primarily gaming on a weekend, 87% played during the holidays, 86% played during the evening, 67% played after school or work, 45% played during their lunch break, 37% played while travelling on public transport, and 35% played before work or school (IGEA 2014). Preferred devices to play games by adults aged 51+ years were PC (91%), console (49%), tablet (40%), mobile phone (35%) and handheld device (7%) (IGEA 2014).

Drawing upon the overview of this section, it is notable that older adults worldwide seem to play digital games. Unfortunately, it is difficult to ascertain the exact number of older adults (aged 65+ years) playing games from the respective publications. For example, the ESA commonly chooses to publish data across three age cohorts (<18 years, 18–49 years and 50+ years), but nevertheless the authors believe that analysing the data of the latter age group in more detail would provide interested parties with a bigger picture of the current situation in the older population. In this context, it is noteworthy that the ESA provides an annual publication of digital gaming trends which is not the case for the ISFE or other associations. Therefore, the authors suggest that more frequent publications from different sources would give interested parties a better opportunity to keep up to date with technology use and digital gaming habits. Overall, the figures across the three continents show a positive attitude towards digital gaming and peripheral devices, including digital game preferences, purchasing habits, online gaming and reasons for game playing.

7.2.4 Digital Gaming in the Domains of Health and Rehabilitation

The field of 'Games for Health' has gained popular interest in a bid to explore and ascertain digital gaming solutions for chronic health conditions (Marston et al. 2016a, b, c; Miller et al. 2013; Bleakley et al. 2013; Hall et al. 2012), while previous work focused predominantly on physical and cognitive effects of digital games (Bleakley et al. 2013). Future research is needed to tailor interventions to the older population.

Hall et al. (2012) undertook a review to ascertain the health outcomes associated with game play by adults aged 65+ years. Results highlighted 13 articles including mental, physical and social health factors, type of game platform, study design and assessments/measurements, and a series of themed summaries. The results showed that there were significant mental health themes arising from the literature, followed by physical and social health outcomes. The respective authors concluded that across the studies in their review, positive effects of health outcomes were displayed, while proposing similar recommendations to that of Miller et al. 2013 in so much as 'robust and rigorous research designs are needed to increase validity and reliability of results' (pp. 194). Finally, the review undertaken by Marston et al. (2016a, b, c) focuses on elderly adults categorized as the oldest old and their

participation in digital game studies across the fields of gerontology and computer science. Marston and colleagues identified 46 articles, while 60% of these articles had been published in gerontology journals, and 8.7% were published in computer science. What is interesting from this review was that no single article primarily focused on the oldest old as their target sample, and few studies had recruited more than 100 participants.

Further analysis of the reviews ascertained 7 primary themes (physiological and psychological health, environment (i.e. nursing home), technology hardware and software, assessment and game technology (i.e. tools, usability issues)), and 34 secondary themes were identified. The most common themes identified from the reviews were hardware technology and assessment. The respective authors of this review proposed several recommendations, initially highlighting the paucity of oldest old engagement in digital game studies, and with this, future studies should recruit oldest old, increase sample size and explicitly report the exact numbers of participants aged 85+ years. While following suit of earlier reviews undertaken by Hall et al. (2012) and Miller et al. (2013) who both proposed rigorous and robust methods in future studies, it needs to be addressed and integrated in conjunction with the inclusion of theoretical perspectives which is an element that Marston and colleagues found limiting.

Across the fields of gerontology, digital game studies and health, researchers have explored the use of digital games and its peripheral hardware (e.g. Wii Balance Board) to investigate and understand whether this type of technology can produce beneficial outcomes for improving the health, wellbeing and lives of older adults, living within their own home or long-term care facility.

Understanding digital games from different domains such as design, motivation, enjoyment and meaning in conjunction with their attributes has been conducted by scholars (De Schutter and Brown 2016; Marston et al. 2014, 2016a, b, c; De Schutter et al. 2014; Marston 2012, 2013a, b; De Schutter and Vanden Abeele 2008; De Schutter 2010; IJsselsteijn et al. 2007; Vanden Abeele et al. 2007); in a bid to comprehend how digital games can play a part in the lives of older adults from different theoretical positons, life course and flow to enhance motivation, gamification and rewards have been studied by these respective scholars. Results from these studies showed several facets associated with engaging older adults with digital games which include needing a purpose, choice, flexibility, and challenge, fostering and facilitating social connectedness, contributing to society, perceiving benefits and incorporating rewarding experiences to encourage and motivate digital game interaction by ageing populations. Moreover, the respective studies have noted usability and accessibility as issues experienced by older adults more so than younger adults, reducing cognitive overload through interface design, and providing adaptability to counterbalance functional limitations (e.g. sensory, memory, executive functioning).

Purpose-built games have been deployed in studies focusing on neurological conditions such as Parkinson's disease (PD) using commercial hardware such as the Microsoft Kinect (Galna et al. 2014). Results showed digital game rehabilitation using commercial hardware was feasible and safe for people with PD. Yet

further interventions should assess the safety, feasibility and efficacy of this technology within the home. Moreover, digital games have been used to assess cognition, and executive control functions within older adults (Goldstein et al. 1997; Basak et al. 2008). The results in these respective studies showed positive trends to deploying digital games in a bid to maintain cognitive functioning as one ages. However, this area of digital games has received a lot of attention over the last 10 years from commercial companies such as Posit Science, Lumos, Nintendo and Cogmed.

7.2.5 eHealth, Digital Gaming, Fall Prevention and Active Ageing

Within the field of fall prevention and fall risk assessment, several studies using purpose-built and commercial technologies and software have been executed (Gschwind et al. 2015a, b; Uzor and Baillie 2014; Reed-Jones et al. 2013; Schoene et al. 2011; Young et al. 2011). With regard to stroke rehabilitation, digital games have been deployed across several studies (Yavuzer et al. 2008; Hijmans et al. 2011; Holden et al. 2007). Many studies in the areas of fall prevention and stroke rehabilitation showed a positive trend and potential benefit of using purpose-built technologies and software and/or commercial software in the daily lives of older adults.

Marston and Smith (2012) in their review focused on studies aimed at fall prevention and stroke rehabilitation and identified 38 articles varying in participants' sample size, commercial software/purpose-built technologies and/or hardware (peripherals) and assessments. A series of recommendations were proposed, and a selection is provided below including: the notion of digital game technology should be available in both clinical and home environments, instructions for using digital game soft/hardware are not always clear, and thus, it should be written in a language that is easily understood (Lange et al. 2009). Patients and users of digital game technology for rehabilitation should receive positive feedback during their therapy sessions. Providing this type of feedback will indicate to the user/patient their level of progress, and in turn, increase self-confidence (Lange et al. 2009). Time is an important issue for patients, support networks and the health practitioners. Setting up the equipment and calibrating individual settings can be time consuming.

Therefore, it was proposed by Marston and Smith (2012) that sessions should be recorded, to provide a full and accurate response to therapists/health practitioners, enabling meaningful results, and a progress review (over a period of time) should be considered. While data storage would also need to be considered, this option was to be implemented. Additionally, digital game activities and having a purpose for game playing are perceived to be important aspects that should be considered during the design phase of software, taking into account the needs and requirements from a clinical/health point of view. Therefore, the proposed recommendations included the need to have several elements integrated into the assessment tools, and

providing the patient/user with a staggered progression. Furthermore, integrating or offering different challenges throughout the game will enable users/patients to maintain their motivation, and by accomplishing a challenge, it is likely one's self-confidence will be increased.

7.3 Mobile Health (mHealth) Apps and Ageing

eHealth is a growing field of study which can benefit and impact upon the lives of many people across different societal pathways. The iStoppFalls study is one example of how eHealth can facilitate positive benefits, relating to our ageing populations. Yet, as a multidisciplinary field and domain, there is still a lack of discussion regarding technology use and behaviour, in so much as understanding the barriers and enablers to taking up technology, the reasons why older adults use technology and understanding their needs and requirements. This chapter explores the use of technology through the eyes of the iStoppFalls project focusing upon the use of digital game technology for use within the field of eHealth and future studies.

Mobile health (mHealth) apps and wearable devices are a technological medium that is gaining greater interest across the fields of health, computer science and human computer interaction. Marston and Hall (2015) discussed game-based approaches such as gamification in relation to mobile (mHealth) apps and how gamification can provide health promotion, prevention and self-management of chronic health conditions. Throughout the respective chapter, Marston and Hall (2015) aimed to define gamification within a healthcare context and the associated components of gamification, identify and ascertain current work within this field and the strategies undertaken. A series of recommendations were proposed for taking this work forward and enhancing game-based approaches such as gamification across the fields of health promotion, prevention and self-management.

Furthermore, a table shows an overview of differing healthcare apps by developers, functionality and motivation, while another table displays the number of mHealth apps that have been developed for chronic health conditions (Marston and Hall 2015, pp. 90). There were several recommendations proposed across research and practice; taking a research perspective, Marston and Hall (2015) proposed future studies should utilize a mixed-method approach relating to data collection of the functionality of gamification and mHealth apps, while also taking a qualitative approach through one-to-one interviews and participatory design workshops with target audiences and stakeholders.

Undertaking pre-/post-assessment of health behaviour components in the initial stages of design that would also fill the paucity of evidence, be it from a small or large RCT, would be fruitful for furthering and enhancing the work in this area. From a practical standpoint and based upon the work by Aitken and Gauntlett (2013) who previously presented six points to the barriers and obstacles of using mHealth apps which also need addressing. Additional suggestions included the need of the design/research teams to consider the appropriation of gamification

Fig. 7.1 Displays how a gamer/user would hold a traditional gamepad. Permission given by Dr. H.R. Marston

components which would be identified through participatory design workshops and access to statistical data from mHealth apps that are being used. Accessing back-end data could be fruitful to understand whether mHealth apps and wearable technologies are beneficial for self-management and prevention of chronic health conditions.

There is a multitude of interactive content available across many digital devices (mobile phones, computers, digital games/consoles and televisions), but this content may not be consumable for older adults, taking into consideration chronic health conditions and age-related impairments such as poor vision, hearing loss and/or impaired cognition. Interacting with digital technologies can vary and include touch, voice, motion and gesture, as well as different in/output devices (mouse/keyboard). At old age, diseases (e.g. arthritis) can play a part in limiting one's interaction with technology, especially playing games through traditional methods such as a gamepad as used by gamers/players engaging on the PlayStation or Xbox consoles (Fig. 7.1). With more innovative approaches found on the Nintendo Wii console via the Wiimote (Figs. 7.2 and 7.3) and in Fig. 7.4, which displays an older adult interacting with the Hills 'n' Skills game developed for the iStoppFalls project, accessed and deployed on the Microsoft Kinect console (e.g. gesture and speech control), interaction may be easier for some, yet remain difficult for others. Digital game interaction may have made strides over the decades from the traditional gamepads to motion, gesture and speech recognition, yet some people who are very unstable on their feet may experience difficulties with limited upper extremity support, and those with impaired cognition due to health and age-related conditions and/or dexterity problems engaging with the Nintendo Wii, and/or the Microsoft Kinect consoles may also have a limited gaming experience.

Figs. 7.2 and 7.3 Displays how a gamer/user would hold a Wii Mote to play the Wii Sports (Boxing and Golf). Permission given by Dr H. R. Marston

Fig. 7.4 Displays a user playing the Hills 'n' Skills exergame developed for the iStoppFalls project. Permission given by Dr. R. Wieching, lead coordinator on the iStoppFalls project

Moreover, one should consider the approach taken to interacting and engaging with mHealth apps via smartphones and tablet devices. Whereby, the general approach is to tap and swipe on the screen and select the necessary information. Conversely, if one has been familiar with pressing a series of buttons on a phone and then is introduced to a new updated model such as Android (Samsung) or iOS

(Apple) smartphone, then the individual will be required to recalibrate their mental models to fit in with their new device. For some younger cohorts, this may not be so difficult, unless they are switching models let us say from an iPhone to a Google Pixel, then a younger person may also face challenges when using their new phone. This would be similar to an older person moving from a phone where buttons are required to be pressed to one which is used by swiping. This is something that requires further exploration in relation to younger cohorts, yet, interaction and engagement affects everyone across the life course, some more than others, especially those who have age-related health issues.

7.4 The iStoppFalls Project and the Digital Device Survey

The eHealth project – iStoppFalls, funded under the EU Framework Programme (FP) 7 stream – was an international project comprising of seven partners, six European and one from Australia. The RCT phase was conducted across three sites (Sydney, Valencia and Cologne), in 2014, and a total of 153 participants aged 65 years and older were recruited.

Participants were randomized into either the intervention group which asked participants to engage with a purpose-built exercise program for 16 weeks, (Gschwind et al. 2014) or the control group who received an educational booklet on general health. The digital device survey, completed by iStoppFalls participants, included computer use, access and ownership; digital game use, access and ownership; length/frequency of computer usage and game playing; type of game genres played or which they would like to play; online gaming habits; social media use; digital device ownership; purchasing habits of digital games; learning how to play games; and hobbies and interests (see supplementary data for a copy of the survey). In this chapter, data relating primarily to digital game use, access and ownership, type of genres played or what the participants would like to play will be presented. Results from the other survey domains can be found in Marston et al. (2016a, b, c).

7.4.1 iStoppFalls Participants and Their Technology Experience and Engagement

Of the 71 participants assigned to the intervention group in the iStoppFalls project, 61 participants completed the survey and only four participants (3 female and 1 male) reported to currently playing games. With 15 participants (9 female and 6 male) reported to have previously played games, two participants did not respond and 42 participants (23 female, 19 male) reported to not ever have played games. Playing games is an activity that can be undertaken on a variety of entertainment

platforms such as PC (desktop), console and digital device (e.g. tablet, smartphone, mobile phone) or via a social media platform.

7.4.2 Ownership of Digital Game Hardware

Two iStoppFalls participants (one female and one male) reported positively to owing a console, with one female participant owning a Nintendo Wii and one male owning a PlayStation 2. Although participants may or may not own a game console, they may have access through friends, children, family members or grandchildren. Two female and five male participants reported to have access to a game console by being able to borrowing one.

Having access to a variety of technologies such as a desktop computer, smartphone, tablet or console allows greater access to digital game engagement, across different game genres and platforms/formats, be it a subscription game such as World of Warcraft, Solitaire, Minecraft or Mystery of Family Cur on Facebook. Of the participants assigned to the intervention a total of 40 participants (21 female and 19 male) reported to having access to a computer to play games.

7.4.3 Preferred Game Genres

Respondents were asked to consider what type of game genres they would like to play. The most popular game genre were sport (37.9%), followed by strategy (31.0%), puzzle (24.1%), role playing and others (n = 5), adventure (6.9%) and simulation (5.2%). In addition, games in the real-time strategy (1.7%), massively multiplayer online role playing (1.7%), action (1.7%), exergame (1.7%) and platform (1.7%) were each preferred by one respondent. Moreover, 8.6% of respondents reported the 'other' genre that they would consider playing, which suggests that respondents would be willing to play games which maybe more attuned to their hobbies and interests or tailored made. None of the respondents considered playing games from the shooter genre.

7.4.4 Online Game Playing

Today online games can be accessed via several hardware technologies. Three participants of the iStoppFalls trial reported to play games online. Participants were asked what type of online games they played. These included games accessed via platforms on social media such as Facebook, via a subscription such as World of Warcraft, or massively multiplayer online games such as Neverwinter Nights, Ultima Online, EverQuest or Final Fantasy. None of the participants reported to

engage with games via these formats/platforms, yet two participants did respond to 'other'. With this in mind, further exploration is needed in so much as why older adults do or do not engage with online games and, for those that do, why they play online games and what type of platforms/formats they play on.

7.4.5 Approaches to Learning How to Play Digital Games

Learning to play games can be undertaken in a variety of different approaches from watching friends, children or grandchildren to engaging with a virtual environment on its own. Participants in the iStoppFalls project reported primarily learning how to play games through a family member and having been self-taught. Additionally, participants reported that their friends and children were also helping them learn how to engage with digital games. Playing games can be difficult, and depending on the game technology, playing games may be easier such as the Nintendo Wii or the Microsoft Kinect which employs more gesture and speech recognition to assist with game play rather than the Sony PlayStation or Microsoft Xbox which employs a gamepad with buttons. Players are expected to execute multiple buttons pressing on the latter two consoles which for some people, in particular older adults, this maybe cumbersome and more difficult due to age-related impairments. Fourteen participants answered positively to the question of 'would you be willing to learn how to play a game?' while 18 participants answered 'unsure' and 24 answered 'no'. These responses indicate that the respective participants are willing to learn how to play digital games, and their preferred methods are via a friend or through self-learning, followed by a family member or a child.

7.4.6 Purchasing Habits of Digital Games and the iStoppFalls Participants

Digital games can be purchased from a variety of outlets including online (e.g. Amazon), supermarkets/grocery stores, or specialist digital game/electrical stores and for multiple occasions (i.e. as a birthday or Christmas present). Very few participants had bought games for themselves. Respondents reported primarily purchasing digital games online (3.4%) for their grandchild (6.9%), as a birthday present (5.2%), as a Christmas present (5.2%) or as a treat (3.4%).

7.5 Lesson's Learned from the iStoppFalls Technology Survey Results?

7.5.1 Older Adults and Gaming

There have been several reviews published, detailing a variety of studies which have utilized technology for health and rehabilitation (Miller et al. 2013; Bleakley et al. 2013; Hall et al. 2012; Marston and Smith 2012). Yet, literature is scarce regarding what type of technology is used by older adults, their purpose for using technology, purchasing habits and social media use. Most of the studies that utilized digital games to facilitate physical activity to improve health and rehabilitation have not reported data associated with technology use, social media, ownership and access of technology, digital game hardware, the type of games played/preferred and approaches to learning how to play games. Further, data regarding whether participants would be willing to learn how to play, online gaming habits, including the type of games played online, the type of platform the game is played on, who they played with and the length and frequency of online gaming habits is scarcely reported.

With the exception of Marston (2012, 2013a, b), there is little information published based on the type of games older adults would want to play and whether they would want games designed and developed based on their hobbies, interests and/or dreams. Yet the authors believe collecting this type of data is important to understand the needs and requirements of technology use of our current ageing populations but also as a means of preparing for the future. However, the needs and requirements for future ageing populations could differ due to younger populations being more experienced with technology and digital gaming.

The results of the completed iStoppFalls surveys showed that digital games are played by adults aged 65 years and older, that games were played on digital devices across all age groups and that there were no significant results for the type of game genres played or preferred, except exergames. Exergames have become a popular subgenre of the sports genre (Marston and McClenaghan 2013; Fencott et al. 2012). Over the last decade, there has been a growing body of academic work which focuses on the utilization of exergames for different purposes, such as rehabilitation, health and wellbeing (Marston et al. 2016a, b, c; Miller et al. 2013; Bleakley et al. 2013; Hall et al. 2012; Marston and Smith 2012) and the experience of enjoyment (Marston 2013a, b). Based on previous literature (Marston 2012, 2013a, b; Bianchi-Berthouze 2007; Harley et al. 2010; Nap et al. 2009; Khoo and Cheok 2006; Voida et al. 2010; Voida and Greenberg 2009), the notion of playing exergames has been executed through the ease of interaction and primarily through the release of the Nintendo Wii. The approaches to engaging with the digital game environment through motion-based technologies and more recently through gesture control (Gschwind et al. 2014, 2015a, b; Marston et al. 2016a, b, c) have afforded audiences who would not necessarily engage with digital games the opportunity to play for fun, rehabilitation or intergenerational gaming.

7.6 Common Challenges in Gaming Research

The results from the international, multicentered RCT – iStoppFalls – showed the exercise program did reduce the physiological fall risk in the study sample. While analyses of subgroups displayed that the participants assigned to the intervention who had greater adherence also improved their postural sway, stepping reaction and executive function (Gschwind et al. 2015a, b). Moreover, analyses of results exploring the usability and acceptability of the iStoppFalls system showed positive usability, user experience and acceptance, based upon the RCT and living lab approaches (Vaziri et al. 2016). However, to the knowledge of the authors, the iStoppFalls project was the first kind of project which entailed an international, multicentered RCT and living lab approach, comprising of three different study sites, using a variety of technologies and digital devices. Future studies should consider exploring the motivation, gender and age in addition to factoring what previous experiences participants have in using technology, the purpose for using technology and exploring overall perceptions and behaviour.

Research projects, be they large or small, may encounter issues which can affect the initial study design, for example, low adherence to an exercise program resulting in less engagement with the digital games, high drop-out rate due to technical difficulties or gamers'/players' lack of understanding/knowledge on how to engage with the technology and/or digital games. Implementing too much technology (e.g. tablet, digital games, menu selection, social media and/or app) could overload participants, especially those who have little or no previous experience of technology use. This could also reduce the confidence of the participants and may cause them to become demotivated and drop out. The number of measures/instruments can vary across different research projects, and in some cases large governmental-funded projects may have access to a wider range of research tools. This in turn may result in participants being overloaded with assessments and, for example, fail to complete surveys with the required amount of attention, because they were already too tired and/or stressed from the other assessments.

The data presented in this book chapter provide an overview concerning important aspects associated with gaming and how older populations relate to the underlying technology and its associated behaviours. While annual statistics are published by the ESA, there is little annual reporting from the United Kingdom or European game industries; albeit the ISFE are attempting to make some headway in this area by publishing a quarterly 'GameTrack Digest' which has been published since the end of 2011 (GameTrack 2016). The content reports the current gaming trends for Germany, Spain and the UK and covers a variety of areas including the percentage of gamers from age 6 to 64 years, weekly hours of gaming, type of games played (i.e. online, apps), types of devices played (i.e. console, handheld, computer, smartphone, tablets) and the profile of gamers across these age groups (i.e. gender).

7.6.1 Gaming, mHealth Apps and Wearables: Recommendations and Outlook

When looking at gaming research in general, future studies may consider undertaking an in-depth qualitative approach such as focus groups, observations and one-to-one interviews to provide an opportunity to dig deeper into the data and to identify common themes and relationships. Future work in this area may also explore the needs, requirements and preferences of older adults, in so much as the type of games suitable for use in a health and rehabilitation setting.

For instance, researchers need to consider the duration of the intervention period when selecting the appropriate study design. Undertaking a mixed-method approach in future studies may support scientists to examine the data to ascertain patterns of usage, preferences, motivations and perceptions of the respective technology used. While future studies should also take into consideration how to enhance and motivate users from an intergenerational standpoint; examining how intergenerational engagement can influence not only fun and entertainment but also enabling the positive benefits of health prevention and self-management. Longitudinal studies are important for understanding the beneficial and positive impacts on health-related rehabilitation, in association to games, yet to date many published studies are conducted over short periods of time.

Since 2010, wearable technologies and mHealth apps have become a popular area of study (Jakicic et al. 2016; Marston and Hall 2015). Yet, Jakicic and colleagues noted in their respective RCT that there was less weight loss over a 2-year period between the intervention and control groups, concluding that such wearable devices which provide feedback associated with one's physical activity may not be so beneficial over the standard weight loss approaches and methods.

Understanding how wearable technologies in conjunction with digital games and mHealth apps is required to address the assessment of quality of life which has previously been measured through gold standard instruments such as the World Health Organization Disability Assessment Schedule (WHODAS) 2.0; the Patient Health Questionnaire (PHQ-9); a nine-item questionnaire used for screening, diagnosing, monitoring and measuring the severity of depression; the European Quality of Life – 5 Dimensions (EQ-5D); the Short Form-36; and 8-item questionnaires (SF-36, SF-8) which can measure one's level of depression, physical and mental health, and activities of daily living.

Several apps have been developed from paper-based instruments such as the physiological profile approach (PPA) to falls risk assessment and prevention, the (Falls Efficacy Scale-International FES-I) assessment (Yardley et al. 2005), the Iconographical Falls Efficacy Scale (icon-FES), (Delbaere et al. 2011) and the Incidental and Planned Activity Questionnaire (IPEQ), (Delbaere et al. 2010) by scientists at the Neuroscience Research Australia (NeuRA), in the field of fall prevention/fall risk, and are available from the App Store, Google Play and BlackBerry App World.

These apps include the *icon-FES* app (Delbaere et al. 2011) which assesses the fear of falling, the *IPEQ app* (Delbaere et al. 2010) which assesses the incidental

and planned exercise levels, the *PPA Sway Path app* (Sturnieks et al. 2011; Lord et al. 2003) which measures the postural sway of a person, the *PPA reaction Time Test* (Lord et al. 2003; NeuRA, https://www.neura.edu.au/apps/) which measures the reaction time of a person, the *Costab app* (Lord et al. 1996) which measures the coordinated stability of a person, the *Trail Making Test app* (Delbaere and Lord 2015) which assesses the visual attention and task switching abilities and the *Low Contrast Sensitivity Test app* (NeuRA, https://www.neura.edu.au/apps/) which assesses the visual contrast sensitivity of a person. All of these apps have the ability to be deployed across different technology devices for use in a clinical assessment. Although the apps outlined above have been adapted for assessment in specific areas, Marston et al. (2015) have previously discussed technology and the deployment of technology within the twenty-first century as a means of assessing quality of life.

Through the quantified self (QS)/self-tracking domain, many people track their activities, nutritional intake and body fluids/minerals. For some, self-tracking is via the process of several apps on their smartphone to monitor their food intake, sleep patterns, sugar intake, menstrual cycle, calories, blood pressure, heart rate and/or physical activity (Singer 2011; Wolf 2010). The QS movement and self-tracking is still a growing field of study, and it is common to see individuals wearing a piece of wearable technology, which they maybe tracking how many steps they walk per day.

However, it is more than that, through electronic components which are easily attached to the skin, it may be possible in the future to measure, assess and monitor a person's heart rate, blood pressure and temperature. Chaotic Moon (https://www.fjordnet.com/offices/austin/) uses electro-conducive paint to ascertain the vital signs. Using this type of paint enables materials to be connected such as the microcontroller with several sensors. Similarly, other research institutes are also following suit in this area of bio-wearables/technologies including the Ulsan National Institute of Science and Technology (UNIST), Korea Advanced Institute of Science and Technology (KAIST) and the University of California San Diego, while Motorola filed a patent on May 3, 2012, titled 'Coupling an electronic skin tattoo to a mobile communication device'.

What is interesting about this work is the essence of taking self-tracking to a different level, enabling items to be attached to the skin, and with more accuracy. Not only could this method of self-tracking impact on the field of QS but also on the medical profession, for example, if such an approach had been tested and validated, the use of bio-wearables could have a massive impact on the lives of pregnant women both in the developed world and in developing countries. Additionally, from the standpoint of our ageing populations, bio-wearables could remotely monitor vital statistics of older adults who may also require assistance or support from health practitioners and support networks.

This chapter has provided an overview of the technology studies associated with digital games and related aspects to ageing and ageing in place. Additionally, the proposal of new technological ideas which the author and colleagues believe are crucial for moving forward in the twenty-first century have also been outlined and

for the forthcoming decades it is certainly going to be interesting in the fields of health, ageing and technology. Being prepared for the future is important while understanding the differences across the life course and ascertaining the importance of sound study design.

Acknowledgements The author(s) disclosed receipt of the following financial support for the research, authorship and/or publication of this article: This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 287361. The Australian arm is funded by an Australian National Health and Medical Research Council (NHMRC) EU collaboration grant (#1038210). The content of the manuscript does not represent the opinion of the European Community or NHMRC. The funding sources have no role in any aspects of this study. Yves J. Gschwind has been financially supported by a research grant from the Margarete and Walter Lichtenstein Foundation, Basel, Switzerland. All other authors are supported by the iStoppFalls project, European Community Grant Agreement 287361. On behalf of the iStoppFalls consortium, we would like to thank all the participants who took part in the study. Trial registration: Australian New Zealand Clinical Trials Registry Trial ID: ACTRN12614000096651. International Standard Randomized Controlled Trial Number: ISRCTN15932647.

References

Aitken M, Gauntlett C (2013) Patient apps for improved healthcare, *From Novelty to Mainstream*. IMS Institute for healthcare informatics

Basak C, Boot WR, Voss MW, Kramer AF (2008) Can training in a real-time strategy video game attenuate cognitive decline in older adults? Psychol Aging 23/4:765–777

Bianchi-Berthouze N, Kim WW, Patel DI (2007) Does body movement engage you more in digital game play? And why? In: Paiva A, Prada R, Picard RW (eds) Affective computing and intelligent interaction second international conference (ACII 2007). Springer, New York, pp 102–113

Bleakley CM, Charles D, Porter-Armstrong A, McNeill MDJ, McDonough SM, McCormack B (2013) Gaming for health: a systematic review of the physical and cognitive effects of interactive computer games in older adults. J Appl Gerontol. doi:10.1177/0733464812470747

Centre for Disease Control and Prevention (2013) Healthy places terminology. Retrieve from https://www.cdc.gov/healthyplaces/terminology.htm. Accessed Dec 2016

De Schutter B (2010) Never too old to play: the appeal of digital games to an older audience. Games Cult 6/2:155–170. https://doi.org/10.1177/1555412010364978

De Schutter B, Brown JA (2016) Digital games as a source of enjoyment in later life. Games and Culture 11(1–2):28–52. doi:10.1177/1555412015594273

De Schutter B, Vanden Abeele V (2008) Meaningful play in elderly life. Presented at the annual meeting of the international communication association, Montreal

De Schutter B, Brown J, Vanden Abeele V (2014) The domestication of digital games in the lives of older adults. New Media & Society. doi:10.1177/1461444814522945

Delbaere K, Lord SR (2015) Validation of a trail-making test developed for iPad. Retrieved from https://www.neura.edu.au/wp-content/uploads/2016/05/Trails-iPad_validation.pdf. Accessed Dec 2016

Delbaere K, Hauer K, Lord SR (2010) Evaluation of the incidental and planned activity questionnaire (IPEQ) for older people. Br J Sports Med 44(14):1029–1034. doi:10.1136/bjsm.2009.060350

Delbaere K, Smith ST, Lord SR (2011) Development and initial validation of the Iconographical falls efficacy scale. J Gerontol A Biol Sci Med Sci 66(6):674–680. doi:10.1093/gerona/glr.019

Entertainment Software Association. (2004). Essential facts about the computer and video game industry 2004. Retrieved from http://www.theesa.com/files/EFrochure.pdf. Accessed Feb 2005

Entertainment Software Association (2005) Essential facts about the computer and video game industry 2005. Retrieved from http://www.tntg.org/documents/gamefacts.pdf. Accessed 27 July 2016

Entertainment Software Association (2006) Essential facts about the computer and video game industry 2006. Retrieved from https://library.princeton.edu/sites/default/files/2006.pdf. Accessed 27 July 2016

Entertainment Software Association (2007) Essential facts about the computer and video game industry 2007. Retrieved from http://www.org.id.tue.nl/IFIP-TC14/documents/ESA-Essential-Facts-2007.pdf. Accessed 27 July 2016

Entertainment Software Association (2008) Essential facts about the computer and video game industry 2008. Retrieved from http://www.org.id.tue.nl/IFIP-TC14/documents/ESA-Essential-Facts-2008.pdf. Accessed 27 July 2016

Entertainment Software Association (2009) Essential facts about the computer and video game industry 2009. Retrieved from http://www.org.id.tue.nl/IFIP-TC14/documents/ESA-Essential-Facts-2009.pdf. Accessed 27 July 2016

Entertainment Software Association (2010) Essential facts about the computer and video game industry 2010. Retrieved from http://isfe.eu/sites/isfe.eu/files/attachments/esa_ef_2010.pdf. Accessed 27 July 2016

Entertainment Software Association (2011) Essential facts about the computer and video game industry 2011. Retrieved from http://www.isfe.eu/sites/isfe.eu/files/attachments/esa_ef_2011.pdf. Accessed 27 July 2016

Entertainment Software Association (2012) Essential facts about the computer and video game industry 2012. Retrieved from http://www.isfe.eu/sites/isfe.eu/files/attachments/esa_ef_2012.pdf. Accessed 27 July 2016

Entertainment Software Association (2013) Essential facts about the computer and video game industry 2013. Retrieved from http://www.isfe.eu/sites/isfe.eu/files/attachments/esa_ef_2013.pdf. Accessed 27 July 2016

Entertainment Software Association (2014) Essential facts about the computer and video game industry 2014. Retrieved from http://www.theesa.com/wp-content/uploads/2014/10/ESA_EF_2014.pdf. Accessed 27 July 2016

Entertainment Software Association (2015) Essential facts about the computer and video game industry 2015. Retrieved from http://www.theesa.com/wp-content/uploads/2015/04/ESA-Essential-Facts-2015.pdf. Accessed 27 July 2016

Entertainment Software Association (2016) Essential facts about the computer and video game industry 2016. Retrieved from http://essentialfacts.theesa.com/Essential-Facts-2016.pdf. Accessed 27 July 2016

Fencott C, Lockyer M, Clay J, Massey P (2012) Game invaders, the theory and understanding of computer games. Wiley, Hoboken. doi:10.1002/9781118347584

Galna B, Jackson D, Schofield G, McNaney R, Webster M, Barry G et al (2014) Retraining function in people with Parkinson's disease using the Microsoft Kinect: game design and pilot testing. J Neuroeng Rehabil 11(60). doi:10.1186/1743-0003-11-60

GameTrack (2016) GameTrack digest: Quarter 1, 2016. Retrieved from http://www.isfe.eu/sites/isfe.eu/files/attachments/gametrack_european_summary_data_2016_q1.pdf. Accessed 4 Aug 2016

Goldstein J, Cajko L, Oosterbroek M, Michielsen M, van Houten O, Salverda F (1997) Videogames and the elderly. Social Behavior and Personality 25(4):345–352

Gschwind YJ, Eichberg S, Marston HR, de Rosario H, Aal K, Ejupi A, Kroll M, Drobics M, Annegam J, Wieching R, Lord SR, Delbaere K (2014) ICT-based system to predict and prevent falls (iStoppFalls): study protocol for an international multicenter randomized controlled trial. BMC Geriatrics

Gschwind Y, Eichberg S, Ejupi A, de Rosario H, Kroll M, Marston H, Drobics M, Annegarn J, Wieching R, Lord SR, Aal K, Vaziri D, Woodbury A, Fink D, Delbaere K (2015a) ICT-based system to predict and prevent falls (iStoppFalls): results from an international multicenter randomized controlled trial. Eur Rev Aging Phys Activ (EURAPA) 12(10)

Gschwind YJ, Schoene D, Lord SR, Ejupi A, Valensuela T, Aal K, Woodbury A, Delbaere K (2015b) The effect of sensor-based exercise at home on functional performance associated with fall risk in older people – a comparison of two exergames interventions. Eur Rev Aging Phys Act 12:11. doi:10.1186/s11556-015-0156-5

Hall AK, Chavarria E, Maneeratana V, Chaney BH, Bernhardt JM (2012) Health benefits of digital videogames for older adults: a systematic review of the literature. Games for Health Journal 1(6):402–410. doi:10.1089/g4h.2012.0046

Harley D, Fitzpatrick G, Axelrod L, White G, McAllister G (2010) Making the Wii at home: game play by older people in sheltered housing. Lect Notes Comput Sci 6389:156–176. http://dx.doi.org/10.1007/978-3-642-16607-5_10

Hijmans JM, Hale LA, Satherley JA, McMillan NJ, King MJ (2011) Bilateral upper-limb rehabilitation after stroke using a movement-based game controller. J Rehabil Res Dev 48(8):1005–1013

Holden MK, Dyar TA, Dayan-Cimadoro L (2007) Telerehabilitation using a virtual environment improves upper extremity function in patients with stroke. IEEE Trans Neural Syst Rehabil Eng 15(1):36–42

IJsselsteijn W, Nap HH, de Kort Y, Poels K (2007) Digital game design for elderly users. In: Proceedings of the 2007 conference on future play, Toronto, pp 17–22. ACM, New York. Doi: 10.1145/1328202.1328206

Interactive Games & Entertainment Association (IGEA) (2014) Digital Australia 14. Retrieved from http://igea.wpengine.com/wp-content/uploads/2013/11/Digital-Australia-2014-DA14.pdf. Accessed 27 July 2016

Interactive Software Federation of Europe (ISFE) (2012) Videogames in Europe: 2012 consumer study. Retrieved from http://www.isfe.eu/industry-facts/statistics. Accessed June 2013

Interactive Software Federation of Europe (ISFE) Germany (2012) Videogames in Europe: 2012 consumer study. Retrieved from http://www.isfe.eu/sites/isfe.eu/files/attachments/germany_-_isfe_consumer_tracker.pdf. Accessed 8 Aug 2016

Interactive Software Federation of Europe (ISFE) Spain (2012) Videogames in Europe: 2012 consumer study. Retrieved from http://www.isfe.eu/sites/isfe.eu/files/attachments/spain_-_isfe_consumer_study.pdf. Accessed 8 Aug 2016

Jakicic JM, Davis KK, Rogers RJ, King WC, Marcus MD, Helsel D, Rickman AD, Wahed AS, Belle SH (2016) Effect of wearable technology combined with a lifestyle intervention on long-term weight loss the IDEA randomized clinical trial. JAMA 316(11):1161–1171. doi:10.1001/jama.2016.12858

Khoo ET, Cheok AD (2006) Age invaders: social and physical inter-generational mixed reality family entertainment. Int J Virtual Reality 5(2):45–50

Kochera A, Straight A, Guterbock T (2005) Beyond 50: a report to the nation on liveable communities – creating environments for successful aging. AARP Public Policy Institute, Washington, DC

Korea Advanced Institute of Science and Technology (KAIST) (2014) Tattoo biobatteries produce power from sweat. ACS Chemistry for Life. Retrieved from https://www.acs.org/content/acs/en/pressroom/newsreleases/2014/august/tattoo-biobatteries-produce-power-from-sweat-video.html. Accessed Dec 2016

Lange B, Flynn SM, Rizzo AA (2009) Game-based telerehabilitaiton. Eur J Phys Rehabil Med 45(1):143–151

Lord SR, Ward JA, Williams P, Zivanovic E (1996) The effects of a community exercise program on fracture risk factors in older women. Osteoporos Int 6(5):361–367

Lord SR, Menz HB, Tiedemann A (2003) A physiological profile approach to falls risk assessment and prevention. Phys Ther 83(3):237–252

Marston HR (2012) Older adults as 21st century game designers. The computer games journal. Whitsun 1(1):90–102

Marston HR (2013a) Digital Gaming Perspectives of Older Adults: Content vs Interaction: Educational Gerontology 39(3):14–208. doi:10.1080/03601277.2012.700817
Marston HR (2013b) Design recommendations for digital game design within an ageing society. Journal of Educational Gerontology 39(2):103–118
Marston HR, Hall AK (2015) Gamification: application for health and health information technology engagement. In: Novak D, Tulu B, Brendryen H (eds) Handbook of research on holistic perspectives in Gamification for clinical practice. Medical Information Science Reference, Hershey, pp 78–104. doi:10.4018/978-1-4666-9522-1.ch005
Marston HR, McClenaghan PA (2013) Play yourself fit: exercise + videogames = Exergames. In: Bredl K, Bösche W (eds) Serious games and multi-user virtual environments in professional development and healthcare. IGI. http://www.igiglobal.com/chapter/play-yourself-fit/75818
Marston HR, Smith ST (2012) Interactive videogame technologies to support independence in the elderly: a narrative review. Games for health Journal 1(2):139–152. doi:10.1089/g4h.2011.0008
Marston HR, Kroll M, Fink D, Eichberg S (2014). Digital game aesthetics of the iStoppFalls exergame. In B. Schouten et al. (Eds). pp. 89–100. Games for Health, 2014. Springer Fachmedien Wiesbaden. doi: https://doi.org/10.1007/978-3-658-07141_12. http://link.springer.com/chapter/10.1007%2F978-3-658-07141-7_12
Marston HR, Freeman S, Musselwhite CBA (2015) Where does quality of life (QoL) fit in the future of technology in the 21st century. Generations Review, British Society of Gerontology Organisation 25(3):8–14
Marston HR, Freeman S, Bishop AK, Beech CL (2016a) Utilization of digital games for older adults aged 85+ years: a scoping review. Games for Health Journal 5(3):157–174. doi:10.1089/g4h.2015.0087
Marston HR, Kroll M, Fink D, de Rosario H, Gschwind YJ (2016b) Technology use, adoption and behaviour in older adults: results from the iStoppFalls project. Educ Gerontol. doi: 10.1080/03601277.2015.1125178
Marston HR, Kroll M, Fink D, Gschwind YJ (2016c) Flow experience of older adults using the iStoppFalls exergames. Special edition. Digital Gaming Ageing Games Cult J 11(1–2):201–222. doi:10.1177/1555412015605219
Miller KJ, Adair BS, Pearce AJ, Said CM, Ozanne E, Morris MM (2013) Effectiveness and feasibility of virtual reality and gaming system use at home by older adults for enabling physical activity to improve health related domains: a systematic review. Age Ageing 0:1–8. doi:10.1093/ageing/aft194
Nap HH, de Kort YAW, Ijsselsteijn WA (2009) Senior gamers: preferences, motivations and needs. Geron 8(4):247–262
Peek ST, Wouters EJ, van Hoof J, Luijkx KG, Boeije HR, Vrijhoef HJ (2014) Factors influencing acceptance of technology for aging in place: a systematic review. Int J Med Inform 83(4):235–248. doi:10.1016/j.ijmedinf.2014.01.004
Peek STM, Aarts S, Wouters EJM (2015) Can smart home technology deliver on the promise of independent living? A critical reflection based on the perspectives of older adults. In: van Hoof J, Demiris G, Wouters EJM (eds) Handbook of smart homes. Springer, Health Care and WellBeing. Cham, pp 1–10
Reed-Jones RJ, Dorgo S, Hitchings MK, Bader JO (2013) WiiFit plus balance test scores for the assessment of balance and mobility in older adults. Gait Posture 36(3):430–433. doi:10.1016/j.gaitpost.2012.03.027
Satariano WA, Scharlack AE, Lindeman D (2014) Aging, place, and technology: toward improving access and wellness in older populations. J Aging and Health 26(8):1373–1389. doi:10.1177/0898264314543470
Schoene D, Lord SR, Verhoef P, Smith ST (2011) A novel video game-based device for measuring stepping performance and fall risk in older adults. Arch Phys Med Rehabil 92(6):947–953. doi:10.1016/j.apmr.2011.01.012
Singer E (2011) The measured life. MIT Technology Review, June 21, 2011. Retrieved from https://www.technologyreview.com/s/424390/the-measured-life/. Accessed Dec 2016
Sturnieks DL, Arnold R, Lord SR (2011) Validity and reliability of the Swaymeter device for measuring postural say. BMC Geriatr 11:63. doi:10.1186/1471-2318*11-63

University of California San Diego (2016) Coupling an electronic skin tattoo to a mobile communication device. US Patent & Trademark Office. Retrieved from http://appft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.html&r=6&p=1&f=G&l=50&d=PG01&S1=%2820131107.PD.+AND+Motorola.AS.%29&OS=PD/20131107+AND+AN/Motorola&RS=%28PD/20131107+AND+AN/Motorola%29. Accessed Dec 2016

Uzor S, Baillie L (2014) Investigating the long-term use of Exergames in the home with elderly fallers. In: SIGCHI conference on human factors in computing systems (CHI'14). doi:10.1145/2556288.2557160, April 26–1st May, 2014

Vanden Abeele V, Husson J, Vandeurzen L, Desmet S (2007) A software approach to computer science: designing & developing games for and with senior citizens. Int J Game Dev 2

Vaziri DD, Aal K, Ogonowski C, Von Rekowski T, Kroll M, Marston HR, De Rosario H, Poveda R, Gschwind Y, Delbaere K, Wieching R, Wulf V (2016) Exploring user experience and technology acceptance for a fall prevention system: Results from a randomized clinical trial and a living lab. European Review of Aging and Physical Activity (EURAPA) 13:6. doi:10.1186/s11556-016-0165-z

Voida A, Greenberg S (2009) Wii all play: the console game as a computational meeting place. In: Proceedings of the ACM SIGCHI conference on human factors in computing systems (CHI 2009), Boston, April 4–9. ACM Press, New York, pp 1559–1568. doi: 10.1145/1518701.1518940

Voida A, Carpendale S, Greenberg S (2010) The individual and the group in console gaming. In: Proceedings of the ACM conference on computer-supported cooperative work (CSCW 2010), Savannah, GA, February 6–10. ACM Press, New York, pp 371–380 doi:10.1145/1718918.1718983

Wolf G (2010) The data-driven life. The New York Times Magazine, 28 April 2010. Retrieved from http://www.Nytimes.Com/2010/05/02/magazine/02self-measurement-t.Html. Accessed Dec 2016

World Health Organization (2013) World population ageing report. Retrieved from http://www.un.org/en/development/desa/population/publications/pdf/ageing/WorldPopulationAgeing2013.pdf. Accessed Feb 2017

Yardley L, Beyer N, Hauer K, Kempen G, Piot-Ziegler C, Todd C (2005) Development and initial validation of the falls efficacy scale international (FES-I). Age Ageing 34(6):614–619

Yavuzer G, Senel A, Atay MB, Stam HJ (2008) "Playstation eyetoy games" improve upper extremity-related motor functioning in subacute stroke: a randomized controlled clinical trial. Eur J Phys Rehabil Med 44(3):237–244

Young W, Ferguson S, Brault S, Craig C (2011) Assessing and training standing balance in older adults: a novel approach using the 'Nintendo Wii' balance board. Gait Posture 33(2):303–305

Hannah R. Marston is a research fellow, in the Health and Wellbeing Priority Research Area (http://healthwellbeing.kmi.open.ac.uk/) in the School of Health, Wellbeing and Social Care, at The Open University, UK. In March 2017, Dr. Marston organized the first digital health and wellbeing symposium as lead of the Digital Health and Wellbeing Special Interest Group in the Health and Wellbeing Priority Research Area. The event was attended by external academics from across the UK and comprised of several external speakers and a panel discussion. She is currently organizing the 2nd Digital Health and Wellbeing conference to be held between 1–3 May, 2018, at The Open University campus. Hannah has published over 20 journal papers and 5 book chapters and currently serves on two editorial boards. Previously, Dr. Marston has worked internationally undertaking fixed-term positions in Germany as a research scientist on the iStoppFalls EU project at the Institute of Movement and Sport Gerontology at the German Sport University Cologne and in Canada as post-doctoral fellow at the University of Waterloo. Hannah interests are multi-cross disciplinary and include digital games, gender, ageing, lifespan, gamification, technology use and health.

Michael Kroll is now working in the International Office at the German Sport University Cologne.

Dennis Fink leads the Sport Youth section of the DJK Sports Association, based in Langenfeld, NRW, Germany. https://www.djk.de/

Rakel Poveda-Puente holds a Master in Social Welfare, a degree in Social Work and Postgraduate Social Gerontology (Universitatde València). Since 1993, Rakel has worked as a Senior Researcher, at the Institute of Biomechanics of Valencia (IBV). Since 2015, Rakel has held the position of Assistant Professor at the Social Work Department of the Universitat de València. She has participated and conducted R&D projects in several national and European calls (AAL, CIP-ICT, Avanza, Plan Nacional). She has published several articles and books in national and international publications. She works in the area of ageing and people with disabilities with a special focus on: characterization of the technologies users and their problematic, as well as the development of methodologies for user friendly design and accessibility.

Yves J. Gschwind studied sport, exercise and health sciences at the University of Basel, Switzerland, and the University of Sydney, Australia. His Ph.D. took place at the University Hospital in Basel where he predominantly worked with older people suffering from cognitive decline. He continued his research focusing on new technologies (ICT) with a postdoc position as a research officer at Neuroscience Research Australia, and then moved on to manage various clinical pharmaceutical trials (phase I–IV).

Chapter 8
The Evolution of Telehealth

Melinda Martin-Khan, Shannon Freeman, Kevin Adam, and Georgia Betkus

Abstract The evolution of telehealth is defined as the change of telehealth over time, and how it is developing into a system of health care delivery and exchange of information for participants over distance. The term 'separated' is becoming less of a key element in the current definition of telehealth as we seek to transition telehealth into an integrated mainstream health care system that is useful for people everywhere and not just for people in rural and remote locations. An integrated telehealth service enables economies of scale that ensure an affordable and efficient system which is available in a timely way, for anyone with access challenges. This ensures that the needs of people in rural and remote areas are more likely to be met but it also creates a more affordable and efficient system. We are now beginning to see that telehealth is not just a second best option if you cannot be there in person, but in some instances, telehealth is the best choice, no matter where you live.

The evolution of telehealth encompasses the time when health care was delivered exclusively in-person, through to the introduction of technology supported health consultations for people who had access challenges, to opportunities that are now available for delivering health care and exchanging health information remotely as part of a multi-faceted health care system which is delivered either in-person or online for people everywhere. Different models of telehealth have evolved to incorporate technologies into the health care system to keep pace with this change in implementation.

M. Martin-Khan
Centre of Research Excellence in Telehealth, Centre for Online Health, Centre for Research in Geriatric Medicine, School of Medicine, The University of Queensland, Level 2, Building 33, Princess Alexandra Hospital, Ipswich Road, Woolloongabba, Brisbane, QLD 4102, Australia

S. Freeman (✉)
School of Nursing, University of Northern British Columbia, 3333 University Way, Prince George, BC, Canada
e-mail: shannon.freeman@unbc.ca

K. Adam
School of Health Sciences, University of Northern British Columbia, 3333 University Way, Prince George, BC, Canada

G. Betkus
School of Interdisciplinary Studies, University of Northern British Columbia, 3333 University Way, Prince George, BC, Canada

H.R. Marston et al. (eds.), *Mobile e-Health*, Human–Computer Interaction Series,
DOI 10.1007/978-3-319-60672-9_8

8.1 Introduction

Telehealth is the delivery of healthcare or the exchange of healthcare information using telecommunication technologies when participants are separated by distance (World Health Organization 2016). The terms telehealth, telemedicine, and telecare are often used interchangeably, and sometimes they have a slightly more nuanced meaning. In some literature, telemedicine is used specifically to refer to clinical service delivery at a distance. Telehealth has been defined to include the broader topic of public health and programs of risk reduction and wellness in relation to population health strategies. Telecare has been used to refer specifically to programs focused on nursing and community support (Richard Wootton et al. 2006). Healthcare crossing all domains of care will be touched on throughout this chapter as we consider the evolution of telehealth. For the purposes of this chapter, we will use the term telehealth in its generic form to encompass all these different approaches to healthcare and the exchange of healthcare information at a distance (Fatehi and Wootton 2012; Wootton et al. 2006).

In this chapter, we will discuss the evolution of telehealth from the time when healthcare was delivered exclusively in person through to the opportunities available because of new technologies for delivering healthcare and exchanging health information remotely. We will consider the approaches to telehealth that have been adopted to incorporate those technologies into the healthcare system and how this has evolved over time.

Telehealth has had a slow uptake in implementation and suffered significant barriers and setbacks. For many early adopters, the opportunities for improving access to equitable healthcare were tangible but have proven difficult to actualize. These barriers included slow internet connections, expensive equipment, difficult equipment to operationalize, no change management process implementation, and limited support for the economic case (Oakley et al. 2001). Telehealth was seen as a boutique solution for technical enthusiasts that was relevant where healthcare solutions were required in situations of necessity that eliminated the need to be practical (such as the Arctic, rural Australia, outer space, and the deep blue sea).

The evolution of telehealth has a parallel journey with the development of the technology and research associated with history of telehealth. The way we think about telehealth has evolved with the technology and with expanding evidence-based practice. Technology has changed in recent years to the extent that many of the initial barriers have been broken down; in that internet speeds have increased, equipment is not as expensive, and the equipment is not as difficult to operate. Many of these changes have had a significant impact on the way telehealth has been practiced in our health services. Telehealth research has moved from a focus on the difference between visual quality of internet speeds, bandwidth data and data compression (Damore et al. 1999; Frankewitsch et al. 2005; Wootton et al. 1997); to reliability of diagnosis (Loane et al. 1998; Martin-Khan et al. 2012; Queyroux et al. 2017); on to patient outcomes, health service implementation and change management. The evolution of telehealth parallels these developments. That is not to say we have stopped doing studies using these initial designs, but we have expanded the

methodological research designs and focused on a broader range of telehealth applications from a research perspective.

In this chapter, evolution of telehealth is defined as the change of telehealth over time and how it is developing into a system of healthcare delivery and exchange of information for participants over distance and that the term "separated" is becoming less of a key element in the current definition of telehealth as we seek to transition telehealth into an integrated mainstream healthcare system.

Consequently, the scope of telehealth has expanded beyond the focus of rural patients. It has moved to include older frail patients in long-term care, older able people living alone at home, active busy people who do not have time to attend doctor's appointments in person, and now all patients.

The broadening of the customer base is enabled by a different approach to the technology solution. The evolving solution moves from one technology option for rural patients in one specialty provided by the healthcare service to a solution that is multifaceted – different technologies depending on the complexity of the health condition, and in some instances, the technology may be provided by the patient. This has enabled a broader customer base from a focus on rural patients to patients in regional and urban areas. Telehealth is at the forefront of supporting the move to including patients as stakeholders in shared care (Richardson et al. 2001; Wootton et al. 2006).

Telehealth is at a crucial point in its evolution. We have moved beyond the initial stages of discovery and justification. We are now moving into a period where we are beginning to understand how to appropriately integrate telehealth as a part of mainstream healthcare without losing what makes telehealth innovative and vital. At the heart of telehealth has been the desire to ensure that people without access receive high-quality healthcare, in a timely manner. As we look at telehealth evolving, there will always be opportunities for communities in need to receive telehealth as a bridge to equitable healthcare.

8.2 Evolution as a Nonlinear Construct

We often think of evolution in a linear fashion. This is usually the case for developments related to technology. Information storage technology has evolved rapidly over the last several decades. For example, the history of computing has seen a progression of changes over time which has enabled smaller devices to be used to store larger quantities of data (Fig. 8.1). There have been great advances from the initial development of portable floppy disks in the early 1970s to the much more compact disks in the early 1980s and DVDs in the mid-1990s which allowed much greater storage capacity than their floppy disk counterparts. Then following was the development of USBs and SD cards which, along with greatly augmented storage capacity allowed for unprecedented mobility and ease of use to the development of the cloud, allows providers to access vast amounts of information from anywhere with an internet connection.

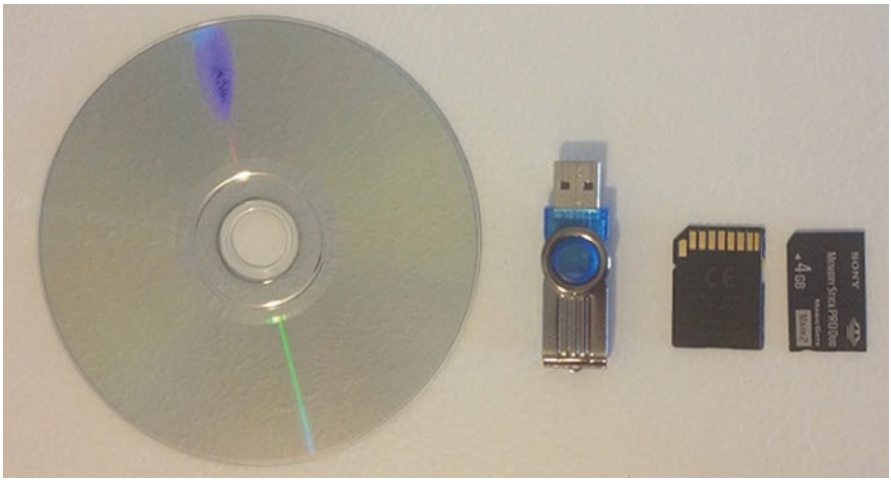

Fig. 8.1 Evolution of data storage for computing

Evolution in telehealth as described in this chapter is not a linear progression with everyone moving in the same direction following individual discoveries or the removal of barriers within one sector or specialty resulting in immediate impacts in adjacent specialties. Telehealth is a complex, multidimensional translational health system, and as such, it is increasingly recognized as a complex intervention to implement within the healthcare system.

8.2.1 Barriers to Implementation

Barriers to widespread telehealth implementation are both simultaneously universal and unique. There has been recognition that implementation of telehealth initiatives without suitable engagement of relevant participants to ensure that all stakeholders understand or perceive potential benefits of the new systems has been a significant barrier to implementation success (Mair et al. 2012). An assumption that individuals or clinical service units will enthusiastically embrace change after identifying the clinical benefits of a telehealth service can lead to poor uptake. There are many significant factors which contribute to successful implementation beyond recognition of clinical benefits or future improved workflow. In relation to the wider stakeholder group, the factors which impact successful implementation include:

- Release from current work commitments to establish protocols for the implementation of new work procedures incorporating telehealth. Training to ensure confidence in the new system
- Time to transition without pressure to perform and meet specific performance outcomes (like budget deadlines or new quality outcomes – i.e., has the system been introduced as a result of an internally enforced measure?)

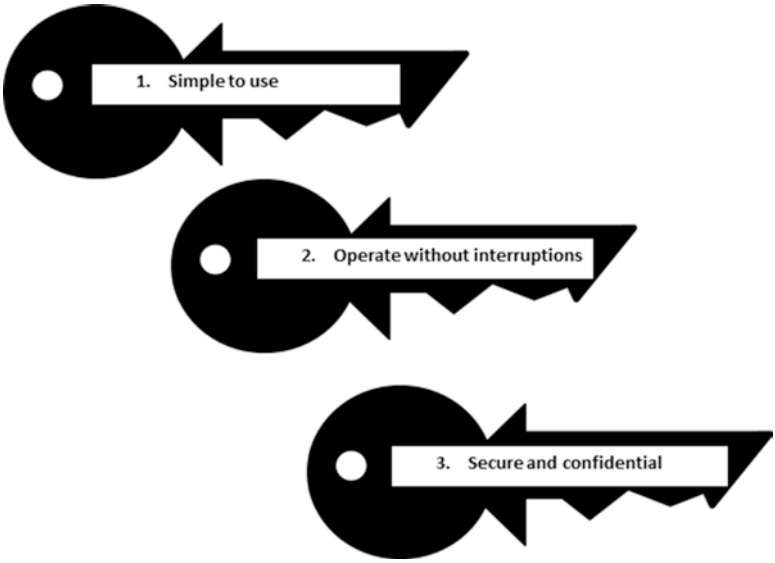

Fig. 8.2 Three key factors for delivering telehomecare to the elderly

- Qualified staff supporting trial implementations which show flexibility in recognizing the growing expertise required to adapt the system to that clinical service unit to ensure it fits within the workflow (Bradford et al. 2016; Mair et al. 2012)

Individual clinician acceptance is a significant contributing factor. It can be a barrier to the introduction of a telehealth element to a service if there is no initial support. Even if a clinician is initially supportive, but that support disappears, lack of clinician acceptance of telehealth can become a subtle barrier to telehealth. Lack of acceptance or misunderstanding by clinicians in relation to each aspect of change (workflow, resourcing, technology problems, consultation format variation) impacts uptake, expansion, and sustainability (Wade et al. 2014). Botsis and Hartvigsen (2008) specifically outlined three key factors which allow for success in the implementation of telehomecare for the elderly and otherwise physically or cognitively impaired. They identified that the system must be simple to use, operate without interruptions, and provide computer security and data confidentiality (Fig. 8.2). It is important that all stakeholders within a clinical health service feel ownership of a telehealth implementation as the barriers to successful implementation are significant and complex (Bradford et al. 2016). This has been identified as particularly important in rural and remote areas when successful implementation involves all stakeholders working together. Relying on one enthusiastic champion to maintain the system will not embed telehealth into the service and help to overcome the barriers to sustainability (Bradford et al. 2016).

It is also important for patient stakeholders to accept telehealth as an effective and innovative way to receive care at home or in their home community. If patients

are not willing to access these services, then the services are not providing value to the patient, community, or healthcare system. One of the barriers to acceptance, and ultimately successful implementation of telehealth, is that many people are not comfortable using technology. Richter et al. revealed that almost half of the participants in their study were not comfortable using computers and one third of the participants did not even have internet access. Richter et al. also found that participants did not trust technology to keep their information safe and secure. Due to these concerns, only 57.8% of participants in Richter's study were interested in receiving telehealth in their homes.

Seniors and underserved populations may have the most to gain from these new health services, but they may also be the most skeptical. These populations did not grow up with these technologies and are not used to their presence. The promise that these technologies will allow them to receive care in their home or community is not enough to compel these populations to accept telehealth. In particular, seniors with dementia are uncomfortable with the technology in their home as they feel like they are being watched or they forget why the technology is in their home (Milligan et al. 2011). It has been found that telehealth that improves daily lives by enabling seniors to perform household tasks is more widely accepted than telehealth that monitors and tracks seniors in their own home (Milligan et al. 2011). Although the technical barriers to implementing telehealth have largely been overcome, patient acceptance is clearly still an issue.

While these common barriers are universal to all telehealth implementations, there are also unique barriers that are recognized due to the issues germane to individual situations. We will discuss three here by way of description (low- to middle income countries; rural telehealth; and home telehealth).

Examples of barriers identified in low- to middle-income countries have included a lack of training and poor infrastructure. The lack of importance given to data for decision-making creates an issue for health information exchange which is important when carrying out telehealth, as electronic health records are often an important enabler for reliable consultations at a distance (Akhlaq et al. 2016). Akhlaq et al. identified examples in Brazil, Kenya, and South Africa where programs incorporated clinical services and health information exchange which worked together to break down the barriers to ensure effective telehealth service delivery in rural areas.

Telehealth as an opportunity for increasing equity for access to healthcare service in rural and remote areas has been a long-term goal (House and Roberts 1977; Martin-Khan et al. 2015b). Many of these reviews (and studies) focus on avoiding travel (Vieira Esteves and Pacheco de Oliveira 2015; Wootton et al. 2011) and increasing the timeliness of access to care. Barriers to this include a lack of vision, no ownership of the service, not being able to adapt the service to meet the needs of the rural area, having equipment that doesn't meet the local needs or can't function on the Internet or data transfer speeds available, and not being economically viable (Bradford et al. 2016).

Increasingly, we are recognizing that travel is not the only issue that telehealth overcomes. Home telehealth is becoming a significant service area of interest.

Barriers specific to this area include the challenges associated with measuring patient-specific outcomes and obtaining measureable outcomes that are linked to telehealth service delivery, in project timeframes to show the tangible benefits of telehealth in the home. Communication between professionals and patient-clinician communication have been identified as a barrier with home telehealth particularly as the home is not designed to be a "clinic" setting and issues in relation to access to technology and financial implications (who will provide the equipment, delivery or patient owned, and how this impacts service sustainability) (Radhakrishnan et al. 2016).

The need to overcome these barriers has meant that the evolution of telehealth does not occur in a liner fashion. Each telehealth implementation is an exploratory exercise which begins with knowledge gained from others but also must be tailored to the individual situation based on the clinical specialty, the geographic location and connectivity opportunities, and the healthcare/workplace gap that is trying to be resolved. For this reason, to date, there have been advances in telehealth technology, advances in telehealth theoretical understandings, advances in telehealth specialty research, and advances in telehealth change management. But this has not meant a shared move forward in telehealth across the field collectively, as each of these advances has been arrived at in different ways at different times and applied differently (Fig. 8.3).

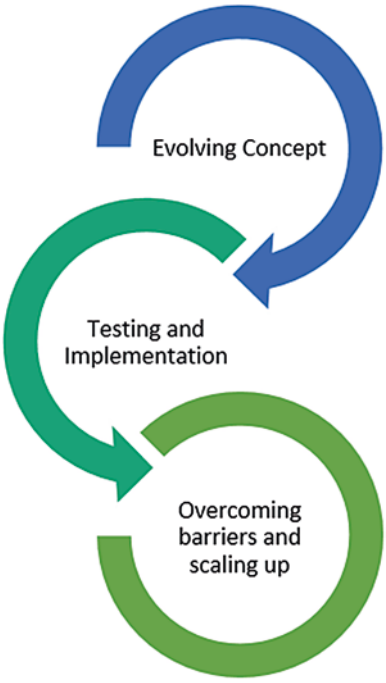

Fig. 8.3 Individual telehealth growth cycle within specialties; growth occurring at different rates across specialties

Before moving on to discuss in detail the key elements of the evolution of telehealth, it is important to reference the two factors in overcoming barriers to implementation of telehealth: steps to successful transition and a framework for research of telehealth implementation.

8.2.2 Successful Transition to Implementation

To ensure that the benefits of telehealth are maximized, Wootton et al. (2006) recommended a strategy that encompassed the following elements (Fig. 8.4):

- Encourage and provide funding for telemedicine research.
- Develop a plan for implementation (once clinical effectiveness and cost-effectiveness have been demonstrated).
- Assess the major structural changes required within organizations to incorporate this method of delivering healthcare.
- Develop a process for training, formulation of practice guidelines, quality control, and continuing audit.
- Consider ethics and medicolegal concerns, human and cultural factors, resistance to change, lack of infrastructure, linguistic differences and illiteracy, and technical and organizational factors (Wootton et al. 2006).

Support with implementation is key to success. We have identified that many publications on service implementation have reported very little implementation on the planning stages of the process (which is not to say that it has not occurred, but it is concerning) (AlDossary et al. 2017b). Applying a planning framework at the initial stages of implementation to identify if a telehealth application is applicable is crucial (AlDossary et al. 2017a), and then using a focused implementation plan (such as this telehealth knowledge translation framework (Theodoros et al. 2016)) is a key element in the initial stages.

Finally, ongoing evaluation of implementation to ensure that referral protocols and safety procedures are being followed and that engagement by all staff within the clinical service unit is occurring (Wade et al. 2014) is required to ensure sustainability from a feasibility and financial perspective (Mair et al. 2012).

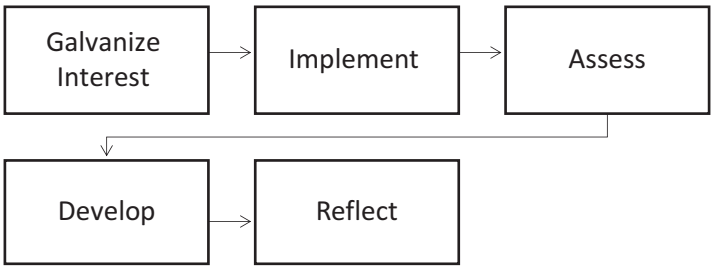

Fig. 8.4 Schematic overview of the successful implementation of telehealth services

8.2.3 Research Support for Implementation

Historically, each specialty has considered the opportunities and challenges in telehealth from within that area of expertise and applied a body of research development work to understand the potential for clinical application with regard to feasibility, reliability, patient safety, and cost. Where possible, potential for generalizability has been taken, but in many instances, the need to consider specialty-specific issues was important for gaining clinical confidence before telehealth implementation could become embedded in the clinical service.

Fatehi et al. (2016) described the stages that are important when planning a research strategy for developing a telehealth intervention for evidence-based practice. These five stages include the following:

A. Concept development

- Need analysis
- Proof of concept
- Technical evaluation

Research teams determine a medical or public health issue, determine a conceivable telehealth service, and attempt to develop an intervention or prototype of the proposed solution. They will also seek to demonstrate that it works and is technically feasible.

B. Service design

- Feasibility
- Validity
- Accessibility
- Cost estimation

A change in the conventional model of care enables the accommodation of the new intervention. Feasibility and accessibility of the telehealth service are evaluated. Information regarding the healthcare needs of patients and their capacity to access care services is crucial for deciding if work should continue. Fatehi et al. define five dimensions of accessibility to consider including cost (affordability), approachability, acceptability, availability and accommodation, and appropriateness.

C. Pre-implementation

- Efficacy
- Usability
- Willingness to pay
- Cost analysis

Health service implementation is complex. Therefore, piloting the intervention to test if the process achieves the expected patient outcomes in a controlled environment of the busy healthcare system (efficacy) is important prior to full implementation. Consideration of the relevance of the telehealth service to all stakeholders

(clinicians, patients, health administrators) needs to be taken into account, along with a detailed cost analysis in order to understand the value for implementing the intervention into practice.

D. Implementation

- Effectiveness
- Adoption
- Scalability
- Generalizability
- Satisfaction
- Cost-effectiveness

The intervention must now be incorporated into telehealth real-world conditions and evaluated for its ability to achieve the desired results. These results should be similar to the results from studies leading up to this point and will be related to patient clinical outcomes. Historically, randomized control trials have been required to determine the effectiveness of a health service intervention, but it is increasingly being recognized that there are other methodologies more feasible for measuring impact in implementation science research. Given the "real-world" implementation, economic analysis should be conducted in partnership with outcome studies.

E. Post implementation

- Utilization
- Quality improvement
- Sustainability
- Social impact
- Cost benefit analysis (23)

Sustainability refers to both the level of usage and the depletion of resources. It is important to consider the long-term viability of telehealth services after the initial implementation period has passed. Two elements that need to be considered are patient and clinician system utilization and, by extension, long-term health outcomes associated with use. Secondly, the economic cost associated with the system and how it may support or deplete associated resources need also to be considered. Information from these two perspectives, when considered together, provides important feedback to managers and policy makers in relation to whether the telehealth service is worth further investment (23).

8.3 The Evolution of Telehealth in Four Stages

While we understand that telehealth has not evolved across the specialties in a linear fashion, we can describe the theoretical concept of telehealth and its evolution in four stages (Fig. 8.5).

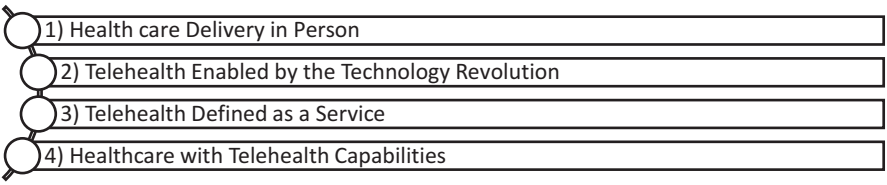

Fig. 8.5 Four nonlinear stages in telehealth evolution

8.3.1 Healthcare Delivery in Person

For centuries, medicine in all of its many traditions has been delivered in person. From the ancient Babylonians and Egyptians to the Greeks who through Hippocrates contributed the Hippocratic oath which is still taken by doctors today, all treatment modalities developed relied almost exclusively on the healer being in close proximity to the patient. To support people who live at a distance from major healthcare centers, different approaches to care delivery have been developed:

- In some instances, policy decisions have been made to support clinicians to travel and reside in locations that are some distance from tertiary centers. For example, graduating clinicians (such as primary care doctors) may be encouraged to take a rural post prior to accepting a metropolitan position.
- A specialist may establish a clinic at a rural or regional hospital and fly to that location on a regular basis (bimonthly) and see patients that have accumulated through a booking system over the course of the period between visits.
- People needing to see a specialist who is not available may travel (with government-assisted travel funding) to the nearest hospital, often 20 h away, via plane or car to see a specialist.
- A medical airplane service flies in and retrieves people with medical acute emergencies and takes them to tertiary hospital centers for the clinical care they need.
- People "make do" and go without if the medical care cannot be sourced in time for what they need or they are too weak or frail to travel to receive it.

In all these examples, there is a delay in receiving the care that people need. This was and is also true for people living in major cities, though it is less obvious. Traffic issues, lack of transport, and frailty could cause difficulties in accessing treatment even if the treatment center is nearby geographically. During this period, there were no other viable alternatives given the lack of developed communication technology, but as these communication systems developed, opportunities to support people grew, and we became more creative and flexible in establishing systems that provided healthcare to those in need.

8.3.2 Telehealth Enabled by the Technology Revolution

While it has been argued that telehealth as a means of communication from a distance is centuries old, as we are avoiding an in-depth discussion of the history of telemedicine (handled well in other texts), we will focus on the recent history of telehealth and the technological advances of the last 150 years.

The advent of the postal service could be regarded as the first use of "store and forward" though minimal technology may be involved. In any case, in the mid-nineteenth century, national postal systems were the norm, and clinicians would send inquiries with case reports to one another and receive feedback. This enabled the diagnosis and care plans to be written for people at much larger distances than before, but the most significant advances came with the advent of telegraphy (1) (Wootton 2006).

The first technology that broke the distance barrier was telegraphy, which eventually morphed into the telephone and the mobile phone as we know it today. In the beginning, being able to speak in "real time" enabled a new level of clinical service, and despite many innovations since, the telephone has been the foundation for telehealth for a long time. It has not been until more recent technological innovations have reached the ease of use and widespread adoption, and widespread adoption of the telephone, that we have seen telehealth become more accepted into mainstream healthcare. For example, imaging is well accepted (X-rays are electronically sent). Issues around privacy are challenging the electronic medical heath record, but the urgency for a solution is pushing this forward. The ease of videoconferencing is seeing this mode of consultation occurring with increasing volume (Skype, Zoom, FaceTime, there are so many options at the click of a button), but the levels of stakeholder acceptability have not broken down yet in the health sector (online clinic medical certificates are not accepted at most universities for students).

As technology capabilities continue to expand, the scope of equipment and services available across healthcare sectors has also grown and with it the potential benefits to healthcare in terms of connectivity and information processing. During this period, telemedicine has been seen as something that is new and must be approached with care before allowing it to be practiced and reimbursed within mainstream healthcare (Krupinski 2009). For this reason, many technologies have been tested within research projects at university hospitals or in silo specialties and have not progressed quickly or directly to mainstream utilization. Initial prototypes are often expensive and clunky which prohibit widespread utilization, and research is slow to keep up with fast technology adaptations (the research which is being implemented to test whether a technology is reliable continues long after the technology has been updated with a newer, more advanced model).

During this period, research often focused on specific equipment qualities (could the patient hear and see the doctor?) and then on equipment factors within specialties (could you make a particular diagnosis within a specialty using that equipment). This meant that often similar studies may be repeated as clinicians were concerned about drawing generalizations in unfamiliar clinical territory (if you could diagnose

a rash using telemedicine, could you then diagnose a wound, or did you need another study to show reliability for wound care rather than just the rash study reliability as generalizable to wound care?). As this is patient care, there is a desire to be cautious so telehealth has many small studies of a similar but different nature; but the general opinion is that the evidence is still "emerging" for many of the specialties as larger-scale studies have not been carried out (Grigsby et al. 2005).

To follow is a description of some of the different telehealth technologies and how they have developed in healthcare and impacted telehealth.

8.3.2.1 Telephone

Telephones have long been the staple of the delivery of healthcare at a distance, utilized for telehealth purposes virtually since its inception (Wooten et al. 2006). This type of telehealth can be defined as the information and support provided via landline telephone (Barlow et al. 2007). Everyone with access to a telephone can participate in this type of telehealth; however, the use of telephones for telehealth has evolved over time.

Originally, family physicians would use landline telephones for consultations with specialist physicians. However, this form of telehealth did not directly include the patient and was proven as an indirect way for patients to receive care (i.e., they would not receive the benefit of the advice until their next visit with their doctor (Hersh et al. 2001). For this reason, telephone use has evolved to include patient-to-healthcare provider interaction (phone conference within a consultation or specialist to patient consultation). Patients can speak directly to a healthcare provider over the phone to ask for advice, relay information, or receive support (McLean et al. 2011). This type of telephone telehealth has proven to support better patient outcomes and reduce unnecessary visits to see the healthcare provider (McLean et al. 2011).

Unfortunately, this form of telehealth does not support users who are deaf and hard of hearing or have visual impairments; if users cannot see the numbers to dial or hear the healthcare provider on the other end of the line, then this service is not providing value. Since vision and hearing are senses that are known to decline as a person ages, it is reasonable to believe that the telephone is not the ideal telehealth solution for the elderly.

The telephone continues to be a useful tool in clinical care, often as a triage for additional telehealth services. The telephone (a landline in this instance) has traditionally been a common community resource (either for every household or shared among neighbors). Using the telephone, clinical staff can assess the urgency for medical care or do follow-up after discharge from hospital. For specialists discussing important matters with older people where their cognitive function is a factor, some cognitive testing by phone may be important. Significant work has been done in relation to testing the reliability of cognitive assessment via telephone to ensure that discussions with older people regarding their medications and personal circumstances are accurate, following the use of reliable cognitive assessments (Martin-

Khan et al. 2010). To support medication adherence for patients with multiple sclerosis, a trial project was carried out which involved home telehealth monitoring (a unit that was connected to the home telephone line and sent customized text messages) and telephone counseling (Turner et al. 2014). The telephone was found to be feasible and acceptable for this form of intervention as a way of encouraging health promotion activities.

Telephone continues to play a crucial role in telemedicine. The introduction of the mobile phone, discussed in detail later, has further cemented the role of telephony in telemedicine. More often than not, telephone is currently excluded from telemedicine literature searches as it is now embedded in the healthcare system as a meaningful part of healthcare delivery.

8.3.2.2 Photos/X-rays: Imaging

The transmission of photos and X-rays is most commonly associated with the field of teleradiology and telepathology. Teleradiology can be defined as the process where X-rays are being administered at one location and the resulting image is being sent to physicians at another site (Omachonu and Einspruch 2010). Telepathology can be defined as the capture of microscopic images which are then forwarded to a pathologist for diagnosis (Dervan and Wootton 1998). These systems, much like store and forward, also do not typically involve direct patient provider interactions.

The World Health Organization (2016) found teleradiology to be the most mature form of telehealth in use, with approximately 60% of all surveyed WHO member countries having an established teleradiology system in country. In fact, teleradiology is so ubiquitous that it is now considered a part of a regular radiology practice. Two thirds of European radiologists surveyed incorporated teleradiology into their clinical practice. Telepathology is a close second to teleradiology, though not as firmly established in the WHO countries surveyed, with just under 40% of countries having an established telepathology service. In addition, 20% of the WHO countries surveyed reported having established pilot telepathology programs (World Health Organization 2016).

8.3.2.3 Videoconference

Videoconference telehealth can be defined as synchronous video consultation between a patient and provider, a provider and provider, or a provider, patient, and specialist (Whited 2006). Videoconferencing systems have been widely implemented across the healthcare setting and are rising in popularity as interactive video-enabled equipment becomes more accessible.

This platform offers many opportunities to enhance care for the elderly. For example, studies have shown that implementation of telehomecare program utilizing videoconferencing components for elderly patients resulted in improved health,

decreased numbers of required clinic visits, lowered health risks, and increased quality of life (Botsis and Hartvigsen 2008). Research has shown that implementation of videoconferencing telehomecare for the elderly can be safely implemented and delivered at lower costs (Finkelstein et al. 2006). Considering the elderly population comprises an ever-increasing proportion of individuals utilizing healthcare systems, it is important to utilize healthcare resources as efficiently as possible; videoconferencing telehealth systems offer yet another avenue to achieve that efficiency.

Despite this, some barriers still exist in utilizing videoconferencing telehealth to the elderly. One of the primary barriers to implementing telehomecare using videoconferencing was user lack of familiarity with the technology. It is frequently reported in the literature that elderly patients often fail to respond when videoconferencing has been initiated and face challenges transmitting additional data to the healthcare team. This indicates that a lack of familiarity and inadequate orientation to the equipment pose an obstacle to their participation. These findings are common but not ubiquitous (Botsis and Hartvigsen 2008). This is unsurprising given the heterogeneity within the platforms being utilized and within the elderly population itself, as the elderly have a higher prevalence of comorbidities such as physical and cognitive impairments which limit their ability to utilize videoconferencing in telehealth (van den Berg et al. 2012).

8.3.2.4 Store and Forward

Store-and-forward healthcare services are defined as the collection of medical information followed by its transmission to then be reviewed by subsequent medical personal. The technology allows for the capture, storage, and transfer of digital still and motion images, as well as text and audio information (Hersh et al. 2006). Utilization of this telehealth does not typically involve direct contact between the patient and provider as they are often separated by both time and space where information may not be interpreted for hours or even days after the information is initially collected (Whited 2006).

Store-and-forward technology is affordable, assessable, and easily implemented into a practice or telehealth programs. Store-and-forward technology has vast potential to reduce barriers and inequities for health services. In comparison to synchronous communication technologies, store-and-forward medical consultations require a relatively low degree of sophistication and are therefore less costly than other telehealth technologies (Whited 2006). Store and forward also has the addition benefit of avoiding the logistical challenge of setting up of implementing a videoconferencing system (Eedy and Wootton 2001).

Store-and-forward technology has been widely adopted by the dermatologists. Their specialty lends itself particularly well to the implementation of the technology. These services typically utilize readily available digital cameras and have easily accessible secure forwarding platforms in which to forward images (Hersh et al. 2006). Studies have shown that store and forward in teledermatology is a reliable

form of teleconsultation and telediagnosis (Whited 2006). Store-and-forward technology has also been incorporated into other clinical specialties including ophthalmology, wound care, cardiology, gynecology, and gastroenterology.

8.3.2.5 Mobile Phones

Mobile health is defined as the use of mobile computing and communication technologies in healthcare and public health (Free et al. 2010). Smartphones, defined as "mobile phones with computer features that may enable them to, with computerized systems, send e-mails, and access the web"(Fiordelli et al. 2013), have seen a surge forward in the usability of handheld/portable technology for healthcare. It has also increased the opportunity for user owned equipment access opportunities.

Mobile phones are owned by a significant proportion of the population and as such have been touted as an opportunity cut down barriers to health inequity. Despite this, there is still a gap in the poorest areas where the cost of a mobile phone (both purchase and ongoing costs) has an impact on the overall family budget and access to ongoing calls and texts. For example, a study in 2012 found that 75% of participants who were South African and living below the poverty line had a mobile phone, but there was no information about what type of phone (James 2015).

For those people with a mobile phone, it has been identified that different features of the mobile phone can provide health and wellness support, for example, smoking cessation, diabetes management, hypertension, weight loss, diet and physical activity, treatment adherence, and disease management. The mobile phone is useful for activities such as reminder, short text messages (SMS), and alerts which result in health benefits for patients (Fiordelli et al. 2013; Guy et al. 2012).

An interesting element to mobile health applications is that patients are in control of the device. The fact that it is personal, intelligent, connected, and with the individual all the time is a very powerful tool. Secondly, the individual finances the device and often purchases health apps personally. Interestingly, minimal research has been done on industry-available apps or products that are available within the phone systems ("native applications" Klasnja and Pratt 2012) and the health benefits attributed to individuals.

8.3.2.6 Robots or Knowbots

Utilizing computing power in a mobile unit with decision-making capacity to provide assistance is a challenging but increasingly feasible healthcare option. This would be commonly known as a robot. A robot is a machine that is capable of carrying out complex tasks, it is generally programed by a computer, and the tasks are automated. Robots have become more useful as they have become more complex with the tasks becoming more intricate and elements of decision-making complexity included in the programing. Artificial intelligence-based applications have led to the creation of new devices being referred to as knowledge robots or "knowbots"

(Ferrante 2005). This can also be referred to as an intelligent agent. An intelligent agent is "any program that can be considered by the user to be acting as an assistant or helper, rather than as a tool in the manner of a conventional direct manipulation interface. An agent should also display some, but perhaps not all, of the characteristics that are associated with human intelligence including: learning, inference, adaptability, independence, creativity, etc."(Lieberman 1997). In thinking about the use of this technology, we need to understand the difference between an agent and a tool as defined by Lieberman. In the early stages, a robot may just be a tool, completing tasks that were specifically assigned and detailed to be carried out, but with more sophisticated computing, the element of agency is introduced, and the "knowbot" is now expected to have a certain level of decision-making within specified boundaries and be acting in support of the people they are working with and not just "completing tasks by rote"; to this end, there is an element of autonomy in their function and decision-making. Siri is an example of an intelligent agent designed to work in support of the person who possesses an iPhone or iPad. There is a certain level of programming and a degree of autonomy. In addition, Siri has some learning capacity and "gets to know" its user.

Knowbots are useful in the care of people with cognitive impairment, and they are starting to be implemented as a support for people who are disabled and for frail, older people. An example is the Paro which is a robot seal used for animal therapy for people with cognitive impairment in residential care. The robot seal responds autonomously to touch and speech of the people around it, and it learns to recognize the people it is with most often (Moyle et al. 2013). Robots are being used to sort and dispense medicines to reduce human error and to count, sort, deliver, and sterilize surgical tools. The RoboCourier made by Swisslog Healthcare Solutions is an autonomous mobile robot that carries information or products in a secure carrier throughout a building (up elevators or through automatic doors) (Lee 2013).

There is concern about how the introduction of robots will impact the workforce. A survey of current attitudes toward robots (knowbots or intelligent agents) identified different attitudes depending on the roles adopted. There tended to be a more negative response to robots involved in a direct caring role, but more accepting toward service or monitoring tasks (Göransson et al. 2008). Lee et al. identified two "opportunities" for robots to impact healthcare: firstly, in replacing positions previously held by employees such as packaging drugs or delivering lab results and secondly in creating telehealth solutions where we weren't aware there was a problem, for example, connection clinicians and patients in meaningful ways that hadn't previously been imagined (Lee 2013). There is also an opportunity for robots to support existing roles where there are current shortages but extra support would improve safety and quality controls without removing existing jobs. Currently, robots, as with all new technologies, are very expensive and as such are outside the reach of most small- to medium-sized hospitals. Therefore, they are mostly used by larger organizations, academic hospitals, or research-funded projects. As with most technology, when the price drops, scalability will improve.

8.3.3 Telehealth Defined as a Service

Telehealth falls under the domain of healthcare innovation which can be defined as the synthesis of a novel concept, idea, service, or product, with the express intent of improving and augmenting care, improving safety, and providing outreach modalities, prevention, and research, with the overarching goal of improving health service quality and patient and provider safety, improving outcomes, increasing efficiency, and improving costs (Omachonu and Einspruch 2010). As technology has evolved, so has telehealth as a service. As previously mentioned, telehealth was originally designed to provide needed healthcare services to residents in rural and remote communities. Overtime, this mission has expanded to include provision of care to residents of urban centers, frail elderly, and busy professionals.

8.3.4 Healthcare with Telehealth Capabilities

The final phase of the telehealth evolution is a healthcare system with telehealth capabilities. Once it is recognized that telehealth has potential to meet a need for almost any demographic, there is a justification for seeking to embed the system within the wider healthcare network. This requires an understanding of how the healthcare system works, the potential of the technology, and a willingness to reengineer healthcare. We know that now technology is becoming less expensive and available to more people, we can tailor opportunities to interact with the healthcare system in a new way. This also requires an awareness that there will be people who still can't afford some of those technologies and that policy decisions will need to ensure that people aren't disadvantaged.

When evolving to an embedded healthcare system, the goal is that each new "telehealth" technology would eventually cease to be a telehealth technology and would become a routine part of the healthcare system. Current examples would include the telephone. There are several papers of telephone telehealth projects (from 20 years ago), but people often exclude it now as "not telehealth." More frequently, electronic medical records are being considered a standard part of the healthcare system and no longer a "telehealth" specialty, but an issue for the wider healthcare community. Sending X-rays electronically used to be a telehealth topic, but now it is routine care both across town and within hospitals. Finally, email (including photos) is sometimes included as telehealth and sometimes excluded as it is very close to being considered "standard." Photos are likely to be included in telehealth longer (wound care, dermatology) as taking a good photo is challenging and impacts diagnosis, so this may not disappear from the telehealth arena in the short term.

There is recognition that for telehealth to be successful, it cannot be a boutique service, it has to be generalizable, there have to be economies of scale, and it has to be something everyone does. It must also be a solution that is matched to the need.

This has only become possible when we truly recognized that telehealth was not just for rural patients or older frail patients, but with a reengineering of the healthcare system, it is for everyone. A silo service that is offered for rural patients, or older patients in residential care, is not necessarily the best service approach available. Until we embed that service within the healthcare system and ensure that all the resources of the healthcare organisation are facilitating those services, then rural and remote patients or older people in residential care won't be receiving the best service possible.

An example is an online appointment and consultation service for primary care and specialist consultation (general practice and outpatients). In the "old days," a person living in rural or remote area would drive or be flown in from your nearest town to see the specialist in the city for your 10-min appointment. After the introduction of videoconferencing, you would go to the local healthcare center and have a video consultation with the specialist organized by her receptionist talking to you and your general practitioner (GP) and posting out a confirmation letter. In this fully evolved model, your GP would tell you that you need to see the specialist (it now doesn't matter whether the hospital is 10 min away and parking is $30 an hour, or 30 h away); and you would go online and request an appointment and upload your referral letter (that had been emailed to you by your GP). You would choose an appointment date that suited you and confirm that video consultation in your office was your preferred option. Following a check of your referral letter, you would receive an email with a link for the video consultation, and on the day of your appointment, you would click on the link and wait in a "consultation room" for the specialist to appear (during your lunch hour – no sick leave required).

At this point, we move away from focusing on individual technology solutions, or individual specialties, and start to consider healthcare systems as a complete unit. Solutions begin to be implemented on a larger scale, for example, telehealth centers within a hospital that provide services to multiple specialties within the center and also support clinicians to run telehealth services from their own units within the hospital (Martin-Khan et al. 2015a).

To come to this point, we need to start thinking about which healthcare design solution is best for a situation and which combination of resources will be most resource efficient, to meet all stakeholder needs and that support quality clinical outcomes. The resultant model may be a combination of "telehealth experiences" and traditional health approaches. We need to be sure to consider that some of the technology may not be owned by the organization but that healthcare can be accessed on resources owned by patients and that some healthcare may be prevention or risk reduction activities and not just acute or chronic care. Equipment that may be used includes mobile phones, iPad, and personal computers. Interactions may include social media, messaging, appointments, and lifestyle support.

Ubiquitous computing refers to unobtrusive computer systems because they enable the use of computers daily without the user being aware of the technology interaction. Ubiquitous computing may refer to voice recognition on telephones, motion detectors, or sensors that measure weight (Ferrante 2005). Ubiquitous computing is particularly important in this phase of telehealth evolution as the line

between telehealth and healthcare is being blurred. The use of intelligent agents within the healthcare system to improve the automation of systems and yet individualize them has potential; this is particularly useful for medications, meal plans, music choices, and leisure activities.

As technology becomes more sophisticated, users will become more comfortable with using it within the healthcare system, and the barriers to daily use will be less challenging. At present, this remains a significant difficulty; telehealth is still struggling to gain wide acceptance (Krupinski 2009). While we must continue to carry out research relating to efficacy, there is a need to focus on change management and an understanding of barriers to implementation. It is important to understand what the real barriers to acceptance are and to support increased knowledge in this area.

8.4 Evolution at Different Rates

There have been significant developments and change in healthcare in the last decade with cost of equipment decreasing and the complexity and capacity of technology increasing. In addition, the ownership of technology has moved from industry to individuals which will lead to an increase in the opportunities for healthcare partnerships in the future of telehealth. The impact of these changes will be felt in different healthcare institutions and in different specialties at different rates, but it is hoped that everyone is evolving toward the same end. For example, 80% of WHO countries surveyed in 2015 reported having a teleradiology program, while 40% of WHO countries reported having a telepsychiatry program (World Health Organization 2016). This further exemplifies the differential rates of change with respect to different specialties incorporating telemedicine within its scope of practice.

Opportunities for telehealth to be ubiquitous in the healthcare system are largely dependent on context, timing, and transformation (Krupinski 2009). In some instances, opportunities will come in one specialty that enable a significant leap forward, supported by policy change and funding, which takes the telehealth elements into the mainstream healthcare infrastructure and embeds it within the system seamlessly. In this way, patients and clinicians don't think of it as "telehealth" anymore but as "healthcare." For another specialty, more layers of research may be required, before policy change or clinician acceptance occur which create the context for transformation.

8.4.1 Research Supporting Evolution

The quality of telehealth published research has improved over time, but telehealth is still not widely implemented, and there remain many barriers to universal acceptance including a paucity of evidence around clinical effectiveness (Grigsby et al. 2005). There have been a number of studies (included in systematic reviews) which have examined clinical outcomes (Estai et al. 2016; Hamine et al. 2015; Hui et al. 2017; Thomas et al. 2014), patient satisfaction (Jenkins-Guarnieri et al. 2015; Liptrott et al. 2017; Mair and Whitten 2000; Williams et al. 2001), other stakeholders (Leibowitz et al. 2003; Shulman et al. 2010), and cost (Kairy et al. 2009; Mistry 2012; Rojas and Gagnon 2008). A significant challenge in research is the rate of technological development and adaption and the comparably slower pace of research. There are instances of telemedicine activity and implementation in some clinical specialties, where research has not been able to be done on efficacy, prior to that implementation (Hersh et al. 2001). The reasons implementation has gone ahead are complex and not always unjustified.

Research methodologies that align well with implementation science and that will enable the study of effectiveness during clinical care are required as many of these technologies (medical records, mobile phones, apps) are being implemented during or before long clinical trials can be implemented. Control groups (as part of randomized control trials or clinical trials) are not feasible in many instances, and yet evidence to support widespread uptake is still required for funding or policy innovation. Building the body of evidence has been difficult because of the challenges around establishing appropriate research models. Increasingly, it is becoming clear that there are challenges for telehealth in terms of the traditional scientific model of randomized control trials (Grigsby et al. 2005; Joseph 2013; Krupinski 2009). Other options that may be more suitable include multi-institutionalized trials or quasi-experimental studies.

8.5 Conclusion

The way we have utilized technology in healthcare has evolved over time. Initially, we were primarily a human-based workforce with limited opportunity to minimize the barriers of distance and time. As technological breakthroughs in infrastructure and computing began, the implications for healthcare were realized. Initially, attention was focused on testing the safety and reliability of individual equipment and infrastructure installations. This advanced to utilizing equipment within specialties for disease-specific support. As telehealth evolved, technology solutions were identified with flagship services for individual health services such as teledermatology or telehomecare. These were stand-alone solutions, often embedded within a larger health service, to provide a telehealth silo service alongside a partner health service. We then moved to focus on increasing the range of stakeholders, from only

providing telehealth to rural patients; we realized that telehealth had relevance to frail older people in large urban areas. Soon we began to understand that telehealth had applicability to everyone, including young, busy professionals who were just too busy to leave the office. It was at this point that telehealth became relevant to all and evolved to the point where there was potential for it to be embedded within the healthcare system.

As Grover identifies, we are still living in the "mainframe era of healthcare, and what we need is the healthcare equivalent of the low cost PC" (Schlender 2003). We are seeking to evolve into the era where telehealth services are all embedded within the mainstream health service, in a way that people no longer notice that they are even using "telehealth" in the same way that they no longer consider the telephone "telehealth." We need to configure healthcare differently to ensure that we can provide it more economically by taking advantage of the unique technologies we now have available to us. We need to be interacting with patients as equal partners in healthcare and be receiving some data/connectivity from them for health interactions. We need to be transitioning some elements of our healthcare activity to intelligent agents to support quality assurance and safety and to provide interactive support for people in need. When we are fully maximizing technology in the health sector, without separating telehealth into a silo for experimental or service purposes, we will know that we have evolved to the next phase of quality healthcare.

References

Akhlaq A, McKinstry B, Muhammad KB, Sheikh A (2016) Barriers and facilitators to health information exchange in low- and middle-income country settings: a systematic review. Health Policy Plan 31(9):1310–1325. doi:10.1093/heapol/czw056

AlDossary S, Martin-Khan MG, Bradford NK, Armfield NR, Smith AC (2017a) The development of a telemedicine planning framework based on needs assessment. J Med Syst 41(5):74

AlDossary S, Martin-Khan MG, Bradford NK, Smith AC (2017b) A systematic review of the methodologies used to evaluate telemedicine service initiatives in hospital facilities. Int J Med Inform 97:171–194

Barlow J, Singh D, Bayer S, Curry R (2007) A systematic review of the benefits of home telecare for frail elderly people and those with long-term conditions. J Telemed Telecare 13(4):172–179

Botsis T, Hartvigsen G (2008) Current status and future perspectives in telecare for elderly people suffering from chronic diseases. J Telemed Telecare 14(4):195–203

Bradford NK, Caffery LJ, Smith AC (2016) Telehealth services in rural and remote Australia: a systematic review of models of care and factors influencing success and sustainability. Rural Remote Health 16(4):1–23

Damore LJ 2nd, Johnson JA, Dixon RS, Iverson MA, Ellison EC, Melvin WS (1999) Transmission of live laparoscopic surgery over the Internet2. Am J Surg 178(5):415–417

Dervan PA, Wootton R (1998) Diagnostic telepathology. Histopathology 32(3):195–198

Eedy DJ, Wootton R (2001) Teledermatology: a review. Br J Dermatol 144(4):696–707

Estai M, Bunt S, Kanagasingam Y, Kruger E, Tennant M (2016) Diagnostic accuracy of teledentistry in the detection of dental caries: a systematic review. J Evid Based Dent Pract 16(3):161–172. doi:10.1016/j.jebdp.2016.08.003

Fatehi F, Wootton R (2012) Telemedicine, telehealth or e-health? A bibliometric analysis of the trends in the use of these terms. J Telemed Telecare 18(8):460–464
Fatehi F, Smith AC, Maeder A, Wade V, Gray LC (2016) How to formulate research questions and design studies for telehealth assessment and evaluation. J Telemed Telecare:1–5
Ferrante FE (2005) Evolving telemedicine/ehealth technology. Telemed J E-Health 11(3):370–383. doi:10.1089
Finkelstein SM, Speedie SM, Potthoff S (2006) Home telehealth improves clinical outcomes at lower cost for home healthcare. Telemed J E-Health 12(2):128–136
Fiordelli M, Diviani N, Schulz PJ (2013) Mapping mHealth research: a decade of evolution. J Med Internet Res 15(5):e95–e95. doi:10.2196/jmir.2430
Frankewitsch T, Söhnlein S, Müller M, Prokosch H-U (2005) Computed quality assessment of MPEG4-compressed DICOM video data. Stud Health Technol Inform 116:447–452
Free C, Phillips G, Felix L, Galli L, Patel V, Edwards P (2010) The effectiveness of M-health technologies for improving health and health services: a systematic review protocol. BMC Res Notes 3(1):250
Göransson O, Pettersson K, Larsson PA, Lennernäs B (2008) Personals attitudes towards robot assisted health care – a pilot study in 111 respondents. Stud Health Technol Inform 137:56–60
Grigsby J, Brega AG, Devore PA (2005) The evaluation of telemedicine and health services research. Telemed J E-Health 11(3):317–328
Guy R, Hocking J, Wand H, Stott S, Ali H, Kaldor J (2012) How effective are short message service reminders at increasing clinic attendance? A meta-analysis and systematic review. Health Serv Res 47(2):614–632
Hamine S, Gerth-Guyette E, Faulx D, Green BB, Ginsburg AS (2015) Impact of mHealth chronic disease management on treatment adherence and patient outcomes: a systematic review. J Med Internet Res 17(2):e52–e52. doi:10.2196/jmir.3951
Hersh W, Helfand M, Wallace J, Kraemer D, Patterson P, Shapiro S et al (2001) Telemedicine for the Medicare population. Evidence report/technology assessment no. 24. AHRQ publication no. 01-E012. Agency for Healthcare Research and Quality, Rockville
Hersh WR, Hickam DH, Severance SM, Dana TL, Krages KP, Helfand M (2006) Diagnosis, access and outcomes: update of a systematic review of telemedicine services. J Telemed Telecare 12(2_suppl):3–31
House A, Roberts J (1977) Telemedicine in Canada. Can Med Assoc J 117(4):386
Hui CY, Walton R, McKinstry B, Jackson T, Parker R, Pinnock H (2017) The use of mobile applications to support self-management for people with asthma: a systematic review of controlled studies to identify features associated with clinical effectiveness and adherence. J Am Med Inf Assoc 24(3):619–632. doi:10.1093/jamia/ocw143
James J (2015) The impact of mobile phones on poverty and inequality in developing countries. Springer, Cham
Jenkins-Guarnieri MA, Pruitt LD, Luxton DD, Johnson K (2015) Patient perceptions of Telemental health: systematic review of direct comparisons to in-person psychotherapeutic treatments. Telemed J E-Health: Off J Am Telemed Assoc 21(8):652–660. doi:10.1089/tmj.2014.0165
Joseph VV (2013) The effects of telehealth on patients with long-term conditions in routine healthcare use and lessons from practical application. In: Telehealth networks for hospital services: new methodologies. IGI Global, pp 103–120
Kairy D, Lehoux P, Vincent C, Visintin M (2009) A systematic review of clinical outcomes, clinical process, healthcare utilization and costs associated with telerehabilitation. Disabil Rehabil 31(6):427–447. doi:10.1080/09638280802062553
Klasnja P, Pratt W (2012) Healthcare in the pocket: mapping the space of mobile-phone health interventions. J Biomed Inform 45(1):184–198
Krupinski EA (2009) History of telemedicine: evolution, context, and transformation. Telemed E-Health 15(8):804–805
Lee J (2013) Robots get to work. More hospitals are using automated machines, but jury's still out on success. Mod Healthc 43(21):20–23

Leibowitz R, Day S, Dunt D (2003) A systematic review of the effect of different models of after-hours primary medical care services on clinical outcome, medical workload, and patient and GP satisfaction. Fam Pract 20(3):311–317
Lieberman H (1997) Autonomous interface agents. Paper presented at the proceedings of the ACM SIGCHI conference on human factors in computing systems
Liptrott S, Bee P, Lovell K (2017) Acceptability of telephone support as perceived by patients with cancer: a systematic review. Eur J Cancer Care. doi:10.1111/ecc.12643
Loane M, Corbett R, Bloomer S, Eedy D, Gore H, Mathews C et al (1998) Diagnostic accuracy and clinical management by realtime teledermatology. Results from the Northern Ireland arms of the UK multicentre Teledermatology trial. J Telemed Telecare 4(2):95–100
Mair F, Whitten P (2000) Systematic review of studies of patient satisfaction with telemedicine. BMJ (Clinical Research Ed) 320(7248):1517–1520
Mair FS, May C, O'Donnell C, Finch T, Sullivan F, Murray E (2012) Factors that promote or inhibit the implementation of e-health systems: an explanatory systematic review. Bull World Health Organ 90(5):357–364. doi:10.2471/BLT.11.099424
Martin-Khan M, Wootton R, Gray L (2010) A systematic review of the reliability of screening for cognitive impairment in older adults by use of standardised assessment tools administered via the telephone. J Telemed Telecare 16(8):422–428
Martin-Khan M, Flicker L, Wootton R, Loh P-K, Edwards H, Varghese P et al (2012) The diagnostic accuracy of Telegeriatrics for the diagnosis of dementia via video conferencing. J Am Med Dir Assoc 13(5). doi:10.1016/j.jamda.2012.03.004
Martin-Khan M, Fatehi F, Kezilas M, Lucas K, Gray LC, Smith AC (2015a) Establishing a centralised telehealth service increases telehealth activity at a tertiary hospital BMC Health Serv Res 15. doi:10.1186/s12913-015-1180-x
Martin-Khan M, Salih S, Rowland J, Wootton R, Gray L (2015b) General practitioners, patients, and care givers support the use of a Telegeriatric memory disorder consultation for older adults. Adv Alzheimer's Dis 4:1–9. doi:10.4236/aad.2015.41001
McLean S, Protti D, Sheikh A (2011) Telehealthcare for long term conditions. BMJ 342:d120
Milligan C, Roberts C, Mort M (2011) Telecare and older people: who cares where? Soc Sci Med 72(3):347–354
Mistry H (2012) Systematic review of studies of the cost-effectiveness of telemedicine and telecare. Changes in the economic evidence over twenty years. J Telemed Telecare 18(1):1–6. doi:10.1258/jtt.2011.110505
Moyle W, Cooke M, Beattie E, Jones C, Klein B, Cook G, Gray C (2013) Exploring the effect of companion robots on emotional expression in older adults with dementia: a pilot randomized controlled trial. J Gerontol Nurs 39(5):46–53. doi:10.3928/00989134-20130313-03
Oakley A, Rademaker M, Duffill M (2001) Teledermatology in the Waikato region of New Zealand. J Telemed Telecare 7(Suppl 2):59–61
Omachonu VK, Einspruch NG (2010) Innovation in healthcare delivery systems: a conceptual framework. Innov J Public Sector Innov J 15(1):1–20
Queyroux A, Saricassapian B, Herzog D, Müller K, Herafa I, Ducoux D et al (2017) Accuracy of Teledentistry for diagnosing dental pathology using direct examination as a gold standard: results of the Tel-e-dent study of older adults living in nursing homes. J Am Med Dir Assoc 18(6):528–532. doi:10.1016/j.jamda.2016.12.082
Radhakrishnan K, Bo X, Jacelon CS (2016) Unsustainable Home Telehealth: a Texas qualitative study. Gerontologist 56(5):830–840. doi:10.1093/geront/gnv050
Richardson WC, Berwick DM, Bisgard J, Bristow L, Buck C, Cassel C (2001) Crossing the quality chasm: a new health system for the 21st century. Institute of Medicine, National Academy Press, Washington
Rojas SV, Gagnon M-P (2008) A systematic review of the key indicators for assessing telehomecare cost-effectiveness. Telemed J E-Health: Off J Am Telemed Assoc 14(9):896–904. doi:10.1089/tmj.2008.0009
Schlender B (2003) Intel's Andy grove: the next battles in tech. Fortune 12:80–81

Shulman RM, O'Gorman CS, Palmert MR (2010) The impact of telemedicine interventions involving routine transmission of blood glucose data with clinician feedback on metabolic control in youth with type 1 diabetes: a systematic review and meta-analysis. Int J Pediatr Endocrinol 2010:1–9. doi:10.1155/2010/536957

Theodoros D, Hill A, Hartley N, Martin-Khan M, Bird D, Russell T et al (2016) Innovation to implementation for Telehealth: a practical guide to knowledge translation in Telehealth. CRE in Telehealth, The University of Queensland, Australia

Thomas SM, Jeyaraman MM, Hodge WG, Hutnik C, Costella J, Malvankar-Mehta MS (2014) The effectiveness of teleglaucoma versus in-patient examination for glaucoma screening: a systematic review and meta-analysis. PLoS One 9(12):e113779–e113779. doi:10.1371/journal.pone.0113779

Turner AP, Sloan AP, Kivlahan DR, Haselkorn JK (2014) Telephone counseling and home telehealth monitoring to improve medication adherence: results of a pilot trial among individuals with multiple sclerosis. Rehabil Psychol 59(2):136

van den Berg N, Schumann M, Kraft K, Hoffmann W (2012) Telemedicine and telecare for older patients—a systematic review. Maturitas 73(2):94–114

Vieira Esteves T, Pacheco de Oliveira S (2015) Telehealth in Brazil: contemporary tool for access to health. Stud Health Technol Inform 216:995–995

Wade VA, Eliott JA, Hiller JE (2014) Clinician acceptance is the key factor for sustainable telehealth services. Qual Health Res 24(5):682–694. doi:10.1177/1049732314528809

Whited JD (2006) Teledermatology research review. Int J Dermatol 45(3):220–229

Williams TL, May CR, Esmail A (2001) Limitations of patient satisfaction studies in telehealthcare: a systematic review of the literature. Telemed J E-Health: Off J Am Telemed Assoc 7(4):293–316

Wootton R, Dornan J, Fisk NM, Harper A, Barry-Kinsella C, Kyle P et al (1997) The effect of transmission bandwidth on diagnostic accuracy in remote fetal ultrasound scanning. J Telemed Telecare 3(4):209–214

Wootton R, Craig J, Patterson V (2006) Introduction to telemedicine, vol 206. Royal Society of Medicine Press, London

Wootton R, Bahaadinbeigy K, Hailey D (2011) Estimating travel reduction associated with the use of telemedicine by patients and healthcare professionals: proposal for quantitative synthesis in a systematic review. BMC Health Serv Res 11:185–195. doi:10.1186/1472-6963-11-185

World Health Organisation (2016) Global diffusion of eHealth: making universal health coverage achievable. Retrieved from: http://apps.who.int/iris/bitstream/10665/252529/1/9789241511780-eng.pdf?ua=1

Melinda Martin-Khan is a health scientist with a joint appointment in the Centre for Online Health and the Centre for Research in Geriatric Medicine, in the Faculty of Medicine at the University of Queensland, Australia. Her gerontology focus is across the fields of telehealth, quality indicator development and dementia with international collaborators. She has worked on projects in long-term care, acute care and the emergency department and has received more than $11M in project funding.

Shannon Freeman is an assistant professor in the School of Nursing at the University of Northern British Columbia, co-president of the British Columbia Psychogeriatric Association, current vice president of the International Association on Geriatrics and Gerontology Coalition of Student Organizations and an interRAI Canada researcher. Dr. Freeman's research interests focus on the health and wellbeing of vulnerable populations with current research projects in the areas of gerontechnology, mental health and wellbeing of older adults and First Nations Elders and long-term care. She is a director of the Prince George Hospice Society and also takes an active role in research examining hospice palliative and end-of-life care.

Kevin Adam is a student in the School of Health Sciences pursuing a degree in Biomedical Sciences at the University of Northern British Colombia. He is a Regional Stakeholder with Canadian Blood Services and has an avid interest in health systems, gerontology, gero-technology, and emergency care. He has participated in policy development within the Canadian blood system, aboriginal intergenerational research, and several literature reviews.

Georgia Betkus is a master's student in Interdisciplinary Studies at the University of Northern British Columbia. She is a research assistant for the Northern Health Authority and holds an undergraduate degree in Health Science from the University of Northern British Columbia. She has contributed to numerous health research initiatives and is currently a project manager for a telehealth initiative in northern British Columbia, Canada.

Part V
Ethics, Theory & Service Provision

Chapter 9
On the Need for Developmental Perspectives in Research on the Potential Positive and Negative Health Effects of Digital Games

Adrienne Holz Ivory and James D. Ivory

Abstract As digital games become increasingly ubiquitous via mobile applications and other widely-used media platforms, game-based health applications and mobile health monitoring technologies are promising tools for eHealth and mHealth. Given the importance of older people as an audience for eHealth and mHealth applications, it is problematic that much research on users and effects of digital games largely neglects developmental approaches and variables. This chapter reviews research on effects of digital games, particularly the health effects of digital games on older people, and suggests how more focus on developmental approaches could guide research on health applications of digital games and game-based eHealth and mHealth tools for older populations.

Digital games represent a promising eHealth tool and mHealth tool, particularly with the growth of mobile game-based health applications and mobile health monitoring technologies. After reviewing the general state of research on positive and negative effects of digital games, this chapter addresses how much of the prominent research on digital games research largely neglects developmental approaches and variables. The chapter summarizes research dealing specifically with the health effects of digital games on older people. Next, the chapter suggests how developmental approaches could be effective in guiding research on the potential health effects of digital games for older populations, then finally calls for more reliance on development as a key aspect in research of digital games' effects, as well as in design of game-based eHealth and mHealth applications.

A.H. Ivory (✉) • J.D. Ivory
Department of Communication, Virginia Tech, 108 Shanks Hall (Mail Code: 0311),
181 Turner Street NW, Blacksburg, VA 24061, USA
e-mail: holz@vt.edu; jivory@vt.edu

H.R. Marston et al. (eds.), *Mobile e-Health*, Human–Computer Interaction Series,
DOI 10.1007/978-3-319-60672-9_9

9.1 Research on Effects of Digital Games: Positive and Negative Potential

The booming commercial and cultural impact of digital games has been accompanied by similarly grand speculation and claims about the health impacts of the medium on its users. Over the past few decades, the most prominent academic discussions about digital games and their possible health effects have dealt with potential negative outcomes, particularly the potential negative social consequences of violent content in digital games (Anderson et al. 2010; Ferguson 2007a, b) and the medium's potential for problematic overuse ("addiction") (Griffiths, 1997, 2008). There has, however, also been ample discussion about the potential positive effects of digital games. Such potential positive outcomes have ranged from improvements in coordination and perception (Green and Bavelier 2006; Kuhlman and Beitel 1991) to developments of advanced social skills (Yee 2006) and to protection against cognitive decline from aging (Basak et al. 2008; Maillot et al. 2012). Granic et al. (2014) describe several potential benefits of gaming, including cognitive, emotional, and social benefits. Game playing may stimulate cognitive skills such as problem-solving skills, spatial skills, and increasing creativity, and may also promote motivation levels among players. There are also emotional benefits of gaming, such as improved mood among players, and social benefits of gaming, such as prosocial skills.

Generally speaking, many of the boldest claims about the existence of powerful positive and negative effects of digital games are likely overstated (Boot et al. 2011; Elson et al. 2014; Ferguson 2010). That said, there is preliminary, if disputed, evidence for a wide range of possible effects of at least some digital games. Digital games are widely and often heavily used by large and diverse audiences, and their engaging and enjoyable features make the medium a likely candidate to serve as an effective vehicle for delivering messages and encouraging rehearsal of behaviors and habits—healthy or otherwise. Therefore, scholars, game designers, and a variety of health advocates are likely to continue to explore the potential effects of games with sustained, or even growing, enthusiasm. Digital games are increasingly seen as a potentially powerful tool for eHealth, the application of technology to provide or enhance health-related services and information (Eysenbach 2001). Increasing ubiquity of mobile devices and mobile health monitoring technology has also made game-based mobile applications a promising tool for mHealth—mobile health—across diverse developmental and socioeconomic populations (Klasnja and Pratt 2012; Lowe and ÓLaighin 2014; Marston and Hall 2016; Miller et al. 2014b).

While digital games have long been stereotypically associated with children, older people have received particular attention as an audience for potential health benefits of digital games. Research has observed that older people express a preference for games as a method for learning (Diaz-Orueta et al. 2012; LeRouge et al. 2013). Given that challenging problem-solving tasks and tests of coordination and visual acuity are two common elements of digital games, researchers have explored the possibility that digital games might be a useful tool for stemming declines in

cognitive, perceptual, and motor skills among older players, as well as promoting mental health and preventing accidents such as falls (Basak et al. 2008; Hall et al. 2012; Maillot et al. 2012). Companies have even marketed some games as beneficial "training" for the brain, though such claims are limited in their empirical support. As with other areas of research on the positive and negative effects of digital games, study findings related to their potential for maintaining the health of older people's bodies and minds is tentative and mixed at best (Boot et al. 2011; Simons et al. 2016). Considering the public health challenges associated with a global increase in the proportion of older people and, consequently, the increase in health concerns associated with older people, the potential health benefits of digital games will likely continue to merit exploration from researchers in search of more conclusive findings about potential positive effects. As research attempts to generate more consistent and conclusive findings regarding the possible positive and negative effects of digital games, with studied outcomes ranging from deviant behavior among children to cognitive skills among older people, one shortcoming of much of this research across its many specific focus areas is limited consideration of developmental approaches, theories, and models as guides for research designs and interpretation of findings.

While much of the research on the effects of digital games is focused very closely on potential effects for age-specific audiences, such as young people potentially made more aggressive by the games' violence or older people potentially aided in thwarting cognitive decline by game tasks, neither the conceptual models nor the empirical designs of much of this research account for the specific developmental characteristics of the populations of interest. In many cases, such research may not even involve participants from appropriate age groups. For example, much research discussing potential negative effects of digital games on children has relied heavily on college student samples (Ferguson 2007a; Sherry 2006).

The tendency for the research on the health effects of digital games to largely ignore the role of developmental stages of life in possible effects mechanisms is a grave oversight. Incorporating developmental perspectives to understand the unique ways that minds and bodies at different stages of life may respond to digital games may be a key to unpacking the currently conflicted and inconclusive bodies of research on various potential effects of digital games. If some possible health effects of digital games are nuanced and conditional, which seems likely given the conflicting findings of much research on the effects of digital games, then developmental approaches may be useful in identifying moderators that show what potential positive and negative effects may be likely among individuals, depending on developmental characteristics such as age. Research on potential benefits of digital games for older people is an area where developmental approaches may be particularly insightful, given that many health concerns that digital games may address among older people are closely associated with specific developmental processes associated with aging.

9.2 The Generally Limited Role of Developmental Approaches in Research on the Effects of Digital Games

The most prominent research dealing with the potential effects of digital games has explored whether digital games influence negative health outcomes in young people, such as aggression and other antisocial behavior (Anderson et al. 2010). The outcomes of this research are mixed, hotly debated, and closely scrutinized (Hall et al. 2011). Several concerns have been raised with the practice and interpretation of the literature on potential negative effects of digital games. One is the presence of flexibility in many studies' measurement of outcomes, which inflates the appearance of significant effects by allowing researchers to sift through multiple versions of an outcome measure to choose a significant version of that measure (Elson et al. 2014). Another issue is a tendency for studies that observe significant effects to be published more than studies that do not (Ferguson and Heene 2012), which inflates the presence of studies observing significant effects in the published literature; this issue has been dubbed "the file drawer problem" (Rosenberg 2005; Rosenthal 1979) in reference to the tendency for studies observing null findings to be relegated to file drawers rather than publication venues. A third issue is the methodological challenge involved in isolating effects of factors such as violent content relative to other factors such as competition (Adachi and Willoughby 2011), which clouds our ability to observe unique effects of violent content. Opinions about the potential negative effects of digital games vary among scholars, and their disagreements are sometimes acrimonious (e.g., Bushman et al. 2015a, b; Griffiths et al. 2016; Hall et al. 2011; Ivory et al. 2015; Markey et al. 2015; Petry et al. 2014; Quandt et al. 2015; Strasburger et al. 2014).

Along with these other issues, however, the research on potential negative effects exemplifies the lack of attention to developmental approaches in the literature on the effects of digital games more broadly, because it has tended to neglect incorporating the role of key biological and psychological changes in adolescence that are closely associated with such negative behaviors (Kirsh 2003). Much of the research on the potential negative effects of digital games is guided by general theories of learned behavior and effects of stimuli on cognitive structures, such as social cognitive theory (Bandura 2001) and the general aggression model (Bushman and Anderson 2002), which acknowledge the existence of individual traits as moderators of effects but do not tend to assign substantial roles to specific developmental factors. As a result, even research targeting implications of the effects of digital games for specific developmental groups, such as children and adolescents, too often fails to include development in its theory or method.

Further, laboratory research on such negative effects of digital games has often used adult college students as participants as a matter of logistical convenience (Ferguson 2007a; Sherry 2006), eschewing the younger digital game players of primary interest to the social questions guiding the research. This has led to a situation where, in many cases, research dealing with participants at one developmental stage of life is generalized to youthful participants at another stage of life with very

different biological and psychological characteristics that are relevant to the negative behaviors of interest. Survey studies have more often directly targeted the youthful populations of interest to much research on digital games' health effects (e.g., Gentile 2009).

These studies however, tend to neglect incorporating developmental approaches in their conceptual explanations and predictions or including variables specifically related to development as potential factors in analyses of health outcomes. The net result is that much of the research on the effects of digital games either studies one age group to make claims about another, or studies an age group presumed to be particularly prone to the effects of digital games without exploring why the group might be developmentally prone to effects, or what members of that group might possess developmental traits particularly conducive to effects (Kirsh 2003).

Much of the literature on potential positive effects of digital games similarly lacks grounding in developmental approaches. Like research on the potential negative effects, the research on potential positive effects of digital games is conflicting and disputed (Boot et al. 2011; Simons et al. 2016). The research on potential positive effects of digital games also too often tends to incorporate the same general theories of learning, imitation, and cognitive effects of stimuli as research on potential negative effects, with little more than a passing nod to developmental approaches and factors (e.g., Gentile and Gentile 2008). Research on potential positive outcomes related to cognition and education has also relied in large part on findings from studies using adult participants, despite being touted as having implications for children and adolescents (Blumberg et al. 2013). Thus, while much of the research exploring both optimism about potential benefits of digital games and concerns about potential harms has focused on implications for audiences at specific developmental stages, such as children, too much of that research has failed to incorporate such developmental factors appropriately in both conceptualizations and methodology.

9.3 Existing Research on the Health Effects of Digital Games for Older People

While much of the research dealing with the effects of digital games, particularly on younger people, has been somewhat negligent of developmental issues with those younger people of interest (Kirsh 2003), research investigating potential health effects of digital games on older users has at least more frequently focused on participants from the age group of interest. In fact, research exploring the effects of digital games on older people has tended to include and even compare findings for samples of older people across a range of ages. For example, a meta-analysis of research on the effects of video games on cognitive function among older adults (Toril et al. 2014) found that while there were a limited number of studies on the topic, the available research was conducted with older adults over a range of ages,

and age appeared to moderate some effects on older people. For instance, one study exploring multitasking performance (Anguera et al. 2013) includes participants varying in age from 20 to 79 years. Meanwhile, some populations, such as older people 85 years of age and older, have not been thoroughly examined in social research involving digital games (Marston et al. 2016a).

Reviews of research on effects of game-based health applications for older people have observed a limited number of studies guided by theory (Hall et al. 2012; Hall and Marston 2014). Reliance on conceptual approaches to development and aging has been limited in many cases, and research on varied outcomes of digital game use for older people is not unified under a model incorporating these different outcomes in a broad understanding of health and aging. Efforts exist to provide theoretical frameworks uniquely tailored to game-based health applications (e.g., AlMarshedi et al. 2016), but they are not widely employed. For instance, lifetime digital game playing is associated with bilateral entorhinal cortex, hippocampal, and occipital gray matter volume (Kuhn and Gallinat 2014).

Among older adults (60–85 years old), custom-designed digital games may benefit cognitive control abilities (Anguera et al. 2013). Meta-analyses (Toril et al. 2014) and systematic reviews (Bleakley et al. 2015; Hall et al. 2012) show positive effects of digital game training on cognitive functions such as attention, memory, reaction time, and global cognition, as well as motor functions, physical outcomes, and prevention of injury from falls. Basak et al. (2008), for example, found gain in executive control functions among older adults trained in a real-time strategy digital game. Similarly, Maillot et al. (2012) found that active digital game training programs for older people improved outcomes such as physical function and cognitive measures of processing speed and executive control.

That said, much of the research on the effects of digital games on perceptual and cognitive skills has been identified as possibly plagued by methodological flaws that limit conclusive interpretation of that research (Boot et al. 2011). A review of research on cognitive training games conducted by Simons et al. (2016) found that while such applications tended to improve performance on the specific tasks involved, there was less evidence for similar improvements in other tasks or general cognitive performance. Similarly, systematic reviews by Molina et al. (2014) and Miller et al. (2014a) found mixed evidence for the effectiveness of digital games as a tool for physical rehabilitation of older people.

Therefore, much of this research is not only lacking conceptual synthesis in terms of understanding the role of the effects of digital games in a comprehensive model of the aging process, but stronger conceptual guidance is needed to produce individual findings that can be conclusively interpreted. Further, researchers have found that age may moderate many effects of digital games on older players (Toril et al. 2014), indicating the importance of a nuanced conceptual and methodological approach to developmental factors in effects of games on older people rather than treating older people as a single homogenous developmental stage group.

9.4 Relevant Developmental Approaches to Aging and Their Potential Application to the Health Effects of Digital Games

Definitions of successful aging have evolved over the years. Initially, literature centered on the biomedical model, which focused on freedom from illness as well as the deficit model of aging, which centers on age-related decline (Tam 2013). More recent approaches account for individual perceptions of aging, such as the model of selective optimization with compensation (see Baltes and Baltes 1990), which aims to understand developmental change across the life span, whereby people select domains to focus their resources, optimize their gains and acquire new skills, and compensate for limitations. While past approaches on aging were one dimensional, newer approaches are more multidimensional and account for the broader dimensions which encompass the aging process, such as social, psychological, and physical aspects.

Young et al. (2009) describe aging as an individual process where each individual ages differently and that successful aging can be achieved when compensations are made for physiological limitations which occur via psychological and social means. They propose successful aging can be measured through a multidimensional model integrating physiological, psychological, and social domains of health. Somewhat similarly, Bronfenbrenner (1993) proposes an ecological model of human development, which stresses that a person's development across the life span needs to be understood in the context of the entire surrounding system. The ecological model proposes five subsystems comprising this ecological system, from the microsystem made up of the person's proximal social environment to the macrosystem made up of broader influences, such as social customs and economic factors.

While these developmental approaches, and others, exhibit some differences in their levels of focus and conceptual mechanisms, each provides a framework of key concepts to be taken into consideration when proposing theoretical and practical applications of digital games to healthier aging. For example, a multidimensional approach to the health benefits of digital games for aging audiences can be rooted in psychological, physiological, and social dimensions of aging, when considering possible outcomes of digital game interventions, possible individual moderators of the effects of games, and possible constraints to use that need to be accounted for in designing games for an older audience. Moreover, research that explores the multidimensional aspects of conceptualizations of aging in concert will be well-suited to synthesize existing research programs on varied dimensions of the effects of games, while also modeling key moderating variables that might define conditional effects. It is also important that digital games meant to educate the elderly and elicit behavior change take into account health behavior models and theories. For instance, Kececi and Bulduk (2012) note that the four health behavior models used most often with the elderly in education, health, and behavioral science articles published during the 2000s include the Theory of Reasoned Action/Planned Behavior, the Health Belief Model, Social Cognitive Theory, and the Transtheoretical Model.

Incorporating such health education-related models in research on game effects for older users would leverage their demonstrated applicability to health education.

Along with accounting for the role of developmental and health concepts in the effects of digital games, researchers also need to account for developmental factors in motivations for playing digital games, in order to better understand why people may choose to engage with games at different points in their life span and what needs and gratifications they use the games to address (Sherry 2013). As Granic and colleagues (2014) state, "We also need information on whether different types of games are not only beneficial but also appropriate to play at specific developmental stages and whether there are specific benefits that are obtained during specific developmental windows and not others" (p. 75). Similarly, elements of game mechanics and challenges most conducive to effective health outcomes must also be modeled. An important learning principle of effective video games is appropriate difficulty level (Eichenbaum et al. 2014). This is a particularly important consideration of video game effects on older players, akin to Vygotsky's (1978) "zone of proximal development" which describes "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky 1978, p. 33).

That is, good games should allow an equilibrium between appropriate levels of difficulty and resultant aggravation and achievement and subsequent satisfaction. Relevant to this equilibrium is the concept of flow (Csikszentmihalyi 1975), which can be understood as a focused and enjoyable state where a user's skill and a task's challenges, including physical exertion (Mueller et al. 2011), are well matched. Flow experiences have been explored in multiple studies examining health applications of games for older people. Robinson et al. (2015) found that self-report measures for some flow experiences were higher among older people using an exercise game-based balance training intervention than among others taking part in traditional balance training. Marston et al. (2016b) measured flow experiences of participants 65 years of age and older, using an established flow measure for older adults (Payne et al. 2011), in their research on a digital exercise game designed to prevent falls.

Marston (2013) similarly measured flow experiences among older people using commercial games on the Nintendo Wii and Sony PlayStation PS2 consoles, finding that flow experiences varied across consoles as well as specific games played. Further, Whitlock et al. (2014) conducted a study that found individual differences and social setting also influenced flow experiences along with game content and challenges. While these studies' findings indicate the importance of flow experiences to older people's responses to digital games and applications, more research is needed to identify optimal challenge and game experience dimensions for older users. Further study examining content of games targeted to older adults may facilitate motivation levels and appropriate levels of difficulty. Examining related experience dimensions such as positive and negative affect using established measures (e.g., Watson et al. 1988) may also provide further insights as to the ideal experience dimensions for game-based digital eHealth and mHealth applications.

Additionally, future research on the effects of digital games at different points in the life span will need to more carefully incorporate developmentally appropriate assessment strategies in operationalization of outcome measures. Measures assessing outcomes such as motor and cognitive function should be designed and applied with circumstances that vary across developmental stages, such as memory and dementia. Much behavioral research with digital games relies on self-report questionnaires, which may not be appropriate to measure some outcomes at all developmental stages.

Validity and feasibility of outcome measures has been a concern in reviews of research related to game-based health applications for older people. (Granic et al. 2014; Miller et al. 2014a; Molina et al. 2014; Wiloth et al. 2016). For some older populations, development of unique measurement instruments may ensure more valid assessment of outcomes from digital games. For example, Wiloth et al. (2016) note problems with the validation of some game-based training outcomes in previous research, particularly for individuals with dementia, and present validation evidence for assessment of motor and cognitive training outcomes using an original "Physiomat" game-based training device for individuals with dementia. Similarly, health outcome measures in research on digital games' effects across the developmental life span should be carefully validated in terms of dimensions such as construct validity, test-retest reliability, and responsiveness to change for developmental groups of interest, as is best practice with clinical and psychometric instruments (Beaton et al. 2001; Portney and Watkins 2015; Wiloth et al. 2016).

Research and theory related to health and development also need to be more consistently integrated into the design of game-based health applications for older people. For instance, Payne et al. (2015) conducted a content analysis of application of health behavior theories in physical activity and exercise mobile game applications. They found that many of the applications included limited application of health behavior theories. As a result, they recommend more collaboration between behavioral health experts and mobile health game application designers. Kececi and Bulduk (2012) describe several potential barriers to the education of the elderly, which include sensory losses (i.e., hearing, touch, and vision deficits), mental illnesses, and chronic diseases. Game designers should take such barriers into consideration, and in-game feedback for players as well as assessment strategies by practitioners and academics should consider these barriers when making learning assessments.

9.5 Conclusion

While the extant literature on the effects of digital games is often problematic in its relative neglect of developmental approaches, there is a strong base of research on the effects of digital games on older players that has employed appropriately aged samples and identified the importance of developmental moderators of such potential effects, even within the broader older population. There is, however, room for more thorough incorporation of multidimensional approaches to psychological,

social, and physical processes of development and aging in the conceptualization, methodology, and interpretation of research exploring how games may affect individuals throughout their life spans. Given the wealth of developmental theory and research that is available, we urge scholars exploring the potential effects of digital games on users of all ages to incorporate developmental approaches and variables more thoroughly in future research, and we urge game designers to integrate developmental and health behavior theory and research findings in game-based eHealth and mHealth applications. More attention to important conditional developmental factors may shed some light on the currently cloudy picture of the potential societal effects of digital games—both positive and negative. Developmental approaches are critical to understanding not only how individuals respond to games throughout the life span, but also why they choose games at different points in their lives and what role game experiences play over the course of their developmental stages.

References

Adachi PJC, Willoughby T (2011) The effect of violent video games on aggression: is it more than just the violence? Aggress Violent Behav 16:55–62. doi:10.1016/j.avb.2010.12.002

AlMarshedi A, Wills G, Ranchhod A (2016) Gamifying self-management of chronic illnesses: a mixed-method study. JMIR Serious Games 4(2):e14. doi:10.2196/games.5943

Anderson CA, Shibuya A, Ihori N, Bushman BJ, Sakamoto A, Rothstein HR, Saleem M (2010) Violent video game effects on aggression, empathy, and prosocial behavior in eastern and western countries: a meta-analytic review. Psychol Bull 136:151–173. doi:10.1037/a0018251

Anguera JA, Boccanfuso J, Rintoul JL, Al-Hashimi O, Faraji F, Janowich J, Kong E, Larraburo Y, Rolle C, Johnston E, Gazzaley A (2013) Video game training enhances cognitive control in older adults. Nature 5104:97–103. doi:10.1038/nature12486

Baltes PB, Baltes MM (1990) Psychological perspectives on successful aging: the model of selective optimization with compensation. In: Baltes PB, Baltes MM (eds) Successful aging: perspectives from the behavioral sciences. Cambridge University Press, New York, pp 1–34

Bandura A (2001) Social cognitive theory: an agentic perspective. Annu Rev Psychol 52:1–26. doi:10.1146/annurev.psych.52.1.1

Basak C, Boot WR, Voss MW, Kramer AF (2008) Can training in a real-time strategy video game attenuate cognitive decline in older adults? Psychol Aging 23:765–777. doi:10.1037/a0013494

Beaton DE, Bombardier C, Katz JN, Wright JG (2001) A taxonomy for responsiveness. J Clin Epidemiol 54:1204–1217. doi:10.1016/S0895-4356(01)00407-3

Bleakley CM, Charles D, Porter-Armstrong A, McNeill MDJ, McDonough SM, McCormack B (2015) Gaming for health: a systematic review of the physical and cognitive effects of interactive computer games in older adults. J Appl Gerontol 34:NP166–NP189

Blumberg FC, Altschuler EA, Almonte DE, Mileaf MI (2013) The impact of recreational video game play on children's and adolescents' cognition. In F. C. Blumberg & S. M. Fisch (Eds.), *Digital Games: A Context for Cognitive Development*. New Dir Child Adolesc Dev 139:41–50. doi:10.1002/cad.20030

Boot WR, Blakely DP, Simons DJ (2011) Do action games improve perception and cognition? Front Psychol 2:226. doi:10.3389/fpsyg.2011.00226

Bronfenbrenner U (1993) Ecological models of human development. In: Gauvain M, Cole M (eds) Readings on the development of children, 2nd edn. Freeman, New York, pp 37–43

Bushman BA, Anderson CA (2002) Violent video games and hostile expectations: a test of the general aggression model. Personal Soc Psychol Bull 28:1679–1686. doi:10.1177/014616702237649

Bushman BJ, Gollwitzer M, Cruz C (2015a) There is broad consensus: media researchers agree that violent media increase aggression in children. Psychology of Popular Media Culture 4:200–214. doi:10.1037/ppm0000046

Bushman BJ, Romer D, Jamieson PE (2015b) Distinguishing hypotheses from hyperbole in studies of media violence: a comment on Markey et al. (2015). Hum Commun Res 41:174–183. doi:10.1111/hcre.12058

Csikszentmihalyi M (1975) Beyond boredom and anxiety. Jossey-Bass, San Francisco

Diaz-Orueta U, Facal D, Nap HH, Ranga MM (2012) What is the key for older people to show interest in playing digital learning games? Initial qualitative findings from the LEAGE project on a multicultural European sample. Games for Health Journal 1:115–123. doi:10.1089/g4h.2011.0024

Eichenbaum A, Bavelier D, Green CS (2014) Video games: play that can do serious good. American Journal of Play 7:50–72

Elson M, Mohseni MR, Breuer J, Scharkow M, Quandt T (2014) Press CRTT to measure aggressive behavior; the unstandardized use of the competitive reaction time task in aggression research. Psychol Assess 26:419–432. doi:10.1037/a0035569

Eysenbach G (2001) What is e-health? J Med Internet Res 3(2):e20. doi:10.2196/jmir.3.2.e20

Ferguson CJ (2007a) Evidence for publication bias in video game violence effects literature: a meta-analytic review. Aggress Violent Behav 12:470–482. doi:10.1016/j.avb.2007.01.001

Ferguson CJ (2007b) The good, the bad, and ugly? A meta-analytic review of positive and negative effects of violent video games. Psychiatry Q 78:309–316. doi:10.1007/s11126-007-9056-9

Ferguson CJ (2010) Blazing angels or resident evil? Can violent video games be a force for good? Rev Gen Psychol 14(2):68–81. https://doi.org/10.1037/a0018941

Ferguson CJ, Heene M (2012) A vast graveyard of undead theories: publication bias and psychological science's aversion to the null. Perspect Psychol Sci 7:555–561. doi:10.1177/1745691612459059

Gentile D (2009) Pathological video-game use among youth ages 8 to 18: a national study. Psychol Sci 20:594–602. doi:10.1111/j.1467-9280.2009.02340.x

Gentile DA, Gentile JR (2008) Violent video games as exemplary teachers: a conceptual analysis. J Youth Adolesc 37:127–141. doi:10.1007/s10964-007-9206-2

Granic I, Lobel A, Engels RCME (2014) The benefits of playing video games. Am Psychol 69:66–78. doi:10.1037/a0034857

Green CS, Bavelier D (2006) Effect of action games on the spatial distribution of visuospatial attention. J Exp Psychol Hum Percept Perform 32:1465–1478. doi:10.1037/0096-1523.32.6.1465

Griffiths MD (1997) Computer game playing in early adolescence. Youth and Society 29:223–227. doi:10.1177/0044118X97029002004

Griffiths MD (2008) Videogame addiction: further thoughts and observations. Int J Ment Heal Addict 6:182–185. doi:10.1007/s11469-007-9128-y

Griffiths MD, van Rooij AJ, Kardefelt-Winther D, Starcevic V, Király O, Pallesen S, Müller K, Dreier M, Carras M, Prause N, King DL, Aboujaoude E, Kuss DJ, Pontes HM, Fernandez OL, Nagygyorgy K, Achab S, Billieux J, Quandt T, Carbonell X, Ferguson CJ, Hoff RA, Derevensky J, Haagsma MC, Delfabbro P, Coulson M, Hussain Z, Demetrovics Z (2016) Working towards an international consensus on criteria for assessing internet gaming disorder: a critical commentary on Petry *et al.* (2014). Addiction 111:167–175. doi:10.1111/add.13057

Hall AK, Marston HR (2014) Gaming and older adults in the digital age of healthcare. In: van Hoof J, Demiris G, Wouters EJM (eds) Gaming and older adults in the digital age of healthcare. Springer International Publishing, Cham, pp 1–9. doi:10.1007/978-3-319-01904-8_55-1

Hall R, Day T, Hall RCW (2011) A plea for caution: violent video games, the supreme court, and the role of science. Mayo Clin Proc 86:315–321. doi:10.4065/mcp.2010.0762

Hall AK, Chavarria E, Maneeratana V, Chaney BH, Bernhardt JM (2012) Health benefits of digital videogames for older adults: a systematic review of the literature. Games for Health Journal 1:402–410. doi:10.1089/g4h.2012.0046

Ivory JD, Markey PM, Elson M, Colwell J, Ferguson CJ, Griffiths MD, Savage J, Williams KD (2015) Manufacturing consensus in a diverse field of scholarly opinions: a comment on bushman, Gollwitzer, and Cruz (2015). Psychology of Popular Media Culture 4:222–229. doi:10.1037/ppm0000056

Kececi A, Bulduk S (2012) Health education for the elderly. In: Atwood CS (ed) Geriatrics. InTech Open Science, Rijeka, pp 153–176. doi:10.5772/1893

Kirsh SJ (2003) The effects of violent video games on adolescents: the overlooked issue of development. Aggress Violent Behav 8:377–389. doi:10.1016/S1359-1789(02)00056-3

Klasnja P, Pratt W (2012) Healthcare in the pocket: mapping the space of mobile-phone health interventions. J Biomed Inform 45:184–198. doi:10.1016/j.jbi.2011.08.017

Kuhlman JS, Beitel PA (1991) Videogame experience: a possible explanation for differences in anticipation of coincidence. Percept Mot Skills 72:483–488. doi:10.2466/pms.1991.72.2.483

Kuhn S, Gallinat J (2014) Amount of lifetime video gaming is positively associated with entorhinal, hippocampal and occipital volume. Mol Psychiatry 19:842–847. doi:10.1038/mp.2013.100

LeRouge C, Ma J, Sneha S, Tolle K (2013) User profiles and personas in the design and development of consumer health technologies. International Journal of Medical Infomatics 82:e251–e268. doi:10.1016/j.ijmedinf.2011.03.006

Lowe SA, ÓLaighin G (2014) Monitoring human health behavior in one's living environment: a technological review. Med Eng Phys 36:147–168. doi:10.1016/j.medengphy.2013.11.010

Maillot P, Perrot A, Hartley A (2012) Effects of interactive physical-activity video-game training on physical and cognitive function in older adults. Psychol Aging 27:589–600. doi:10.1037/a0026268

Markey PM, Males MA, French JE, Markey CN (2015) Lessons from Markey et al (2015) and Bushman et al (2015): Sensationalism and integrity in media research. Hum Commun Res 41:184–203. doi:10.1111/hcre.12057

Marston HR (2013) Digital gaming perspectives of older adults: content vs. interaction. Educ Gerontol 39:194–208. doi:10.1080/03601277.2012.700817

Marston HR, Hall AK (2016) Gamification: applications for health promotion and health information technology engagement. In: Novák D, Tulu B, Brendryen H (eds) Handbook of research on holistic perspectives in gamification for clinical practice. IGI Global, Hershey, pp 78–104

Marston HR, Freeman S, Bishop KA, Beech CL (2016a) A scoping review of digital gaming research involving older adults aged 85 and older. Games for Health Journal 5:157–174. doi:10.1089/g4h.2015.0087

Marston HR, Kroll M, Fink D, Gschwind YJ (2016b) Flow experience of older adults using the iStoppFalls exergame. Games and Culture 11:201–222. doi:10.1177/1555412015605219

Miller KJ, Adair BS, Pearce AJ, Said CM, Ozanne E, Morris MM (2014a) Effectiveness and feasibility of virtual reality and gaming system use by older adults for enabling physical activity to improve health-related domains: a systematic review. Age Ageing 43:188–195. doi:10.1093/ageing/aft194

Miller AS, Cafazzo JA, Seto E (2014b) A game plan: gamification design principles in mHealth applications for chronic disease management. Health Infomatics Journal 22:184–193. doi:10.1177/1460458214537511

Molina KI, Ricci NA, de Moraes SA, Perracini MR (2014) Virtual reality using games for improving physical functioning in older adults: a systematic review. J Neuroeng Rehabil 11:156–175. doi:10.1186/1743-0003-11-156

Mueller F, Edge D, Vetere F, Gibbs MR, Agamanolis S, Bongers B, Sheridan JG (2011) Designing sports: a framework for exertion games. In: Chi '11: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 2651–2660. doi:10.1145/1978942.1979330

Payne BR, Jackson JJ, Noh SR, Stine-Morrow EAL (2011) In the zone: flow state and cognition in older adults. Psychol Aging 26:738–743. doi:10.1037/a0022359

Payne HE, Moxley V, MacDonald E (2015) Health behavior theory in physical activity game apps: a content analysis. JMIR Serious Games 3(2):e4. doi:10.2196/games.4187

Petry NM, Rehbein F, Gentile DA, Lemmens JS, Rumpf H-J, Mößle T, Bischof G, Tao R, Fung DSS, Borges G, Auriacombe M, Ibáñez AG, Tam P, O'Brien CP (2014) An international consensus for assessing internet gaming disorder using the new DSM-5 approach. Addiction 109:1399–1406. doi:10.1111/add.12457

Portney LG, Watkins MP (2015) Foundations of clinical research: applications to practice, 3rd edn, revised. Pearson/Prentice Hall, Upper Saddle River

Quandt T, Van Looy J, Vogelgesang J, Elson M, Ivory JD, Consalvo M, Mäyrä F (2015) Digital games research: a survey study on an emerging field and its prevalent debates. J Commun 65:975–996. doi:10.1111/jcom.12182

Robinson J, Dixon J, Macsween A, van Schaik P, Martin D (2015) The effects of exergaming on balance, gait, technology acceptance and flow experience in people with multiple sclerosis: a randomized controlled trial. BMC Sports Sci Med Rehabil 7(8). doi:10.1186/s13102-015-0001-1

Rosenberg MS (2005) The file-drawer problem revisited: a general weighted method for calculating fail-safe numbers in meta-analysis. Evolution 59:464–468. doi:10.1554/04-602

Rosenthal R (1979) The file drawer problem and tolerance for null results. Psychol Bull 86:638–641. doi:10.1037/0033-2909.86.3.638

Sherry JL (2006) Would the great and mighty Oz play doom? A look behind the curtain of violent video game research. In: Messaris P, Humphreys L (eds) Digital media: transformations in human communication. Peter Lang, New York, pp 225–236

Sherry JL (2013) The challenge of audience reception: a developmental model for educational game engagement. In F. C. Blumberg & S. M. Fisch (Eds.), *Digital Games: A Context for Cognitive Development*. New Dir Child Adolesc Dev 139:11–20. doi:10.1002/cad.20027

Simons DJ, Boot WR, Charness N, Gathercole SE, Chabris CF, Hambrick DZ, Stine-Morrow EAL (2016) Do "brain training" programs work? Psychol Sci Public Interest 17:103–186. doi:10.1177/1529100616661983

Strasburger VC, Donnerstein E, Bushman BJ (2014) Why is it so hard to believe that media influence children and adolescents? Pediatrics 133:571–573. doi:10.1542/peds.2013-2334

Tam M (2013) Perceptions of successful ageing and implications for late-life learning. Stud Contin Educ 35:281–298. doi:10.1080/0158037X.2012.746228

Toril P, Reales JM, Ballesteros S (2014) Video game training enhances cognition of older adults: a meta-analytic study. Psychol Aging 29:706–716. https://doi.org/10.1037/a0037507

Vygotsky L (1978) Interaction between learning and development. In: Cole M, John-Steiner V, Scribner S, Souberman E (eds) Mind in society: the development of higher psychological processes. Harvard University Press, Cambridge, MA, pp 79–91

Watson D, Clark LA, Tellegen A (1988) Development and validation of brief measures of positive and negative affect: the PANAS scales. J Pers Soc Psychol 54:1063–1070. doi:10.1037/0022-3514.54.6.1063

Whitlock LA, McLaughlin AC, Leidheiser W, Gandy M, Allaire JC (2014) Know before you go: feelings of flow for older players depends on game and player characteristics. CHI PLAY '14, 277–286. doi:10.1145/2658537.2658703

Wiloth S, Lemke N, Werner C, Hauer K (2016) Validation of a computerized, game-based assessment strategy to measure training effects on motor-cognitive functions in people with dementia. JMIR Serious Games 4(2):e12. doi:10.2196/games.5696

Yee N (2006) The demographics, motivations, and derived experiences of users of massively multi-user online graphical environments. Presence Teleop Virt 15:309–329. doi:10.1162/pres.15.3.309

Young Y, Frick KD, Phelan EA (2009) Can successful aging and chronic illness coexist in the same individual? A multidimensional concept of successful aging. J Am Med Dir Assoc 10:87–92. doi:10.1016/j.jamda.2008.11.003

Adrienne Holz Ivory is an assistant professor in the Department of Communication at Virginia Tech. Her research focuses on media effects, health communication and media portrayals of gender, race and sexuality.

James D. Ivory is an associate professor in the Department of Communication at Virginia Tech. His research interests include the content, users and social impact of video games, simulations and virtual environments.

Chapter 10
Open Issues in Designing Home Care Technologies

Angela Di Fiore and Francesco Ceschel

Abstract Home care concerns the management of disparate physical impairments at home of the patients. Nowadays, it is being increasingly applied as it improves both the quality of life of the patient and the quality of care. This chapter aims to provide an overview concerning the recurring issues found while identifying requirements and user's needs for home care technologies. We present a series of reflections from the literature to clarify the main factors that may support or hinder the design of effective solutions for this domain. Indeed, the design of technologies for home care often faces several complexities, such as social, communicational and organizational challenges. The goal of this chapter is to underline the relevance of the definition of appropriate social requirements and to address the right key points of attention, in order to best manage the complexity of home care.

10.1 Introduction

The population of Europe is ageing rapidly, and according to the literature, in 20 years most of the citizens will be part of the over 65 cohort (World Health Organization 2002; Gesano et al. 2009; Fernández-Ballesteros et al. 2013). Since ageing may lead to physical impairments and since the ageing population is increasing, there is a rising demand for home care services (European Commission 2015; Delloitte 2016).

This phenomenon is pushing the healthcare sector to enhance home services to allow care at home (Christensen and Grönvall 2011). Home care is an umbrella concept that refers to "the care provided by professionals to a person in her/his own

A. Di Fiore (✉)
InterAction Lab, Department of Information Engineering and Computer Science, University of Trento, Trento, Italy
e-mail: angela.difiore@unitn.it

F. Ceschel
Life Participation Group, Department of Information Engineering and Computer Science, University of Trento, Trento, Italy
e-mail: francesco.ceschel@unitn.it

H.R. Marston et al. (eds.), *Mobile e-Health*, Human–Computer Interaction Series,
DOI 10.1007/978-3-319-60672-9_10

home with the ultimate goal being not only to contribute to patients' life quality (…) but also to replace hospital care with care in the home" (Thomé et al. 2003, p. 871).

Home care concerns the management of physical impairments, such as chronic and degenerative diseases (Postema et al. 2012). Several studies recognized that home care has the potential to increase patients' quality of life, to decrease costs of healthcare, and to leave patients in places where they are emotionally attached to (Bodenheimer 2008; Koch 2006; Postema et al. 2012, Delloitte 2016). Home care is a complex phenomenon, being characterized by a dynamic context that concerns a network of stakeholders with heterogeneous and conflicting needs (Christensen and Grönvall 2011; Wagner et al. 1996; Wagner 2000; WHO 2008). Indeed, home care engages several stakeholders in multisited care activities, involving both care professionals (such as nurses, family doctors, specialists) and family caregivers. Due to the intertwinement of actors, care activities, agendas and knowledge, the coordination of the care activities, the information exchange and the management of the care plans have a central role in home care.

In this scenario, technology is perceived as a relevant asset, having a great potential in supporting the complexity of providing care at home (Delloitte 2016). In particular, home care technologies have to deal with interrelations between places, healthcare providers, individuals' needs, sensibilities, data and information exchange (McGee-Lennon 2008). According to the literature, there is an emerging need of technologies that can support assisted living through home care services since "the existing systems are poorly aligned with the care that older populations require" (Delloitte 2016, p. 5). Due to the human and organizational complexity that characterizes home care, there is a peculiar demand in solutions that can support home care practices, backing coordination and communication (Abowd et al. 2006). The potential of technology can become a call for actions for designers and researchers, in particular in relation to mobile technologies (Beer and Takayama 2011; Delaney 2015).

Recent trends in design conceive reality and human practices as dynamic and constantly changing; they focus on the ontological problem of the attempt of formalizing the reality through the definition of the requirements of a technology (Dourish and Bellotti 1992; Ehn 2008; Akama 2015; Moran and Anderson 1990). If this problem is relevant in every design process, it is even more central in designing for a domain like home care. Home care contexts are generally known for being characterized by unpredictable events and extreme micro-social variability (Strauss 1984; Corbin and Strauss 1984).

In light of the issues described above, this chapter is an introduction to designing information technologies for home care contexts. This work addresses some key points of attention in the definition of users' needs in the domain of home care. In particular, the identification of these key points of attention has the goal to provide a shortlist of conceptual instruments that can guide designers while facing the complexity of the home care domain.

In the first section, we highlight the positive contribution of three computer science approaches in the definition of the requirements of a technology. Requirements are the criteria that define the technical and social features of a future technology (Van Lamsweerde 2009). In this chapter, we focus specifically on social requirements. We discuss computer science approaches that are related to the definition of the requirements, with particular attention to their contribution about dealing with dynamic human contexts and, specifically, home care contexts.

In the second section, we discuss the features that characterize home care settings, and we highlight some of the open issues that can be useful to consider when working in such contexts.

In the discussion, after we synthesize the arguments presented in the preceding section, we draw attention to a shortlist of key points we believe fundamental to consider when designing technologies for home care.

10.2 Approaches in Defining Social Requirements

In this section, we discuss the approaches in computer science that, in our best knowledge, can inform the definition of requirements in dynamics and situated contexts, such as home care. We address specifically the concept of social requirement, which refers to requirements that focus on the reconciliation of the society and individuals' needs and not on technical – hardware and software – aspects (Whitworth 2009). This concept "is centred around knowing which (and how) social arrangements need to be satisfied" by a technology (Ackerman 2000, p. 195). We propose the concept of social requirements as an intellectual tool that can guide the design processes for home care technologies, informing the investigation of the users' needs. It is an interesting resource in a design process, because it can be a bridge between different approaches in computer science that provide positive contribution in understanding, formalizing and reflecting on users' needs and technology constraints.

In this section we address three computer science approaches that deal with social requirements and user's needs: Computer-Supported Cooperative Work (CSCW), Participatory Design (PD) and Requirement Engineering (RE).

Social requirement is a concept proposed by CSCW. In our opinion it can be a nexus between approaches that focus on the variability of human reality (such as Participatory Design) and the ones that are more on the formalizations that are needed to develop a technology (such as Requirement Engineering). In this section we analyse the positive contribution of these approaches in defining social requirements and users' needs in dynamic contexts, in order to assemble the potential of this fascinating intellectual tool.

10.2.1 Computer-Supported Cooperative Work (CSCW)

Computer-Supported Cooperative Work is an approach that investigates the role of technology in fostering interaction and collaboration among individuals within their working environment (Dourish and Bellotti 1992). Computer-Supported Cooperative Work is a transformative and design-oriented approach, which focuses on how to best design a technology to support collaboration among humans, and, hence, it attributes much attention to the social requirements a technology should embody. Indeed, it is engaged in a more epistemological conception of requirements, focusing on the so-called social requirements that refer more to the process of understanding of users' needs and their work practices in order to develop better technologies (Bannon et al. 1988; Schmidt and Bannon 1992). In the light of this peculiar attention, CSCW broadly focuses also on healthcare contexts (Fitzpatrick and Ellingsen 2013).

One of the most relevant epistemological problems in CSCW concerns the definition of requirements and is known as the so-called sociotechnical gap. Sociotechnical gap is a concept that refers to "the great divide between what we know we must support socially and what we can support technically" (Ackerman 2000, p. 180). This gap represents the main challenge of the approach we are discussing here and highlights the complexity of the social dimension in relation to the intrinsic and ontological limits of technology. Computer-Supported Cooperative Work stresses the importance of the social requirements, because they allow to evaluate which are the boundaries within which technical solutions can fully address social needs. For this reason, this approach attributes considerable importance to the experience of professionals who work within a working environment; they can identify the limits of a technology and, consequently, the sociotechnical gap (Bannon et al. 1988; Schmidt and Bannon 1992; Ackerman 2000).

Computer-Supported Cooperative Work considers both the social and technological side, concerning a working environment as matters in co-evolution. Therefore, it ascribes much attention to the work practices and how these practices are shaped by the setting of the technologies in place (Ackerman 2000; Bannon et al. 1988).

Studies on CSCW (Bannon et al. 1988; Schmidt and Bannon 1992) highlight how technology, in a few cases, lacks to support and satisfy the social complexity that characterizes the interactions among workers. According to Bannon and Schmidt (1989, p. 360) "Computer Supported Cooperative Work should be conceived as an endeavour to understand the nature and requirements of cooperative work with the objective of designing computer based technologies for cooperative work arrangements".

As we mentioned above, the literature stresses the importance of understanding the users' needs, their work practices and how their work is articulated and interconnected among individuals. In particular, there are various contributions that address healthcare contexts and provide a clear picture about the complexity of the work

practices and the use of technologies within it (Fitzpatrick and Ellingsen 2013). With regard to the healthcare in particular, CSCW stresses to investigate on the influence of the technology on three levels, in order to better identify the sociotechnical gap: (1) technologies do not provide enough "complexity" to support a wider "social use"; (2) technologies are not socially flexible and are anchored to fixed roles, without considering the diversity of professional roles and work tasks; (3) technologies do not allow sufficient ambiguity and mostly aim to create quantifiable and measurable, tasks and processes (Ackerman 2000).

Overall, CSCW appears the appropriate approach to support the comprehension of social requirements. Therefore, it seems to provide the lens to better comprehend complex sociotechnical environments, such as healthcare contexts.

10.2.2 Participatory Design

Participatory Design is a democratic approach to design that aims to involve and commit users into the decision-making processes, as it will lead to the development of a new technology conceived to support the class of users involved in the design process itself (Simonsen and Robertson 2012). Participatory Design is a design-oriented approach that aims to empower users through different techniques that support participation and involvement. Participatory Design – which is strongly linked to CSCW – primarily focuses on social requirements; it emphasizes that "human activities are carried out in cooperation with others and so new technologies need to be designed to support cooperation" (Simonsen and Robertson 2012, p. 8). For this reason, Participatory Design stresses the need to comprehend how to enhance commitment and foster cooperation and mutual support among future users. In other words, Participatory Design calls for a deep understanding of the needs of the user(s). In this, the design process is paramount, because it is conceived as way to structure the future relations among humans and between humans and technology (Light and Akama 2014). Moreover, in this process of participation, a technology is conceived as a 'future thing' that will, eventually, derive from a further negotiation among the future users, which will adopt and adapt the technology itself (Ehn 2008). That is why, through Participatory Design, designers aim to develop technologies in accordance with the user's perspective, in order to improve their working and daily practices (Simonsen and Robertson 2012).

Across the literature on Participatory Design, participants are deemed the main actors of the process, as they will assume the role of future users once the design is completed. Conversely, the role of researchers and designers is limited to facilitating, validating, adjusting and monitoring the design path (Simonsen and Robertson 2012).

The strongest contribution of Participatory Design is the enhancement of human relations through participation and mutual understanding, and conceiving a design

process (Akama 2015). Indeed, the process primarily focuses on understanding the individuals involved (target user group), the relations they established within the group and in which context these relations take place. This helps to display the design and the subsequent development of technologies, as the co-evolution of services and human practices (Suchman and Trigg 1995). This is the reason why the Participatory Design community focuses on an approach centred on the human perspective, rather than drawing the attention on mere technical requirements.

The Participatory Design literature offers a wide variety of studies on the epistemological problem of empowering people, both with the technology and with the Participatory Design process itself (Halskov and Hansen 2015). Yet, the literature is also rich with empirical papers that illustrate the process and the most effective techniques used to engage users in order to grasp their needs (Halskov and Hansen 2015). These studies present an extensive empirical knowledge on narrative techniques, qualitative methods and concepts, which support the understanding of situated contexts where new technology may be adopted. On the one hand, the peculiar attention of Participatory Design for situated contexts makes it particularly appropriate for healthcare contexts. On the other hand, this led to the avoidance of holistic models to guide the design processes. In Participatory Design there is no reference explicitly made to the concept of social requirements; however, its attention to the micro-social level provides several methodological and ethical reflections on participation but limits the understanding of the macro level.

10.2.3 Requirement Engineering

Requirement Engineering is a discipline originally established in the 1970s, with the aim to investigate which requirements should lead the development of a software (Zave and Jackson 1997). Differently from Software Engineering, which aims to design 'things right', the purpose of Requirement Engineering is to design the 'right thing' by identifying and documenting specific requirements (Boehm 1981). Requirement Engineering provides models and taxonomies that use diagrams, mathematical analysis and unified modeling language (UML) notation to support the formalization of technical and social requirements (Van Lamsweerde 2009). This approach investigates the reality from a macro perspective, focusing on the standardization and generalization of how a technology should be designed.

Requirement Engineering has a transformative rationale, and it encompasses four main phases: (1) requirement elicitation, which refers to the gathering of requirements working with prospective users; (2) requirement specification, in which the requirements are classified and defined; and (3) requirement validation, which is the phase in which the requirements are organized and tested (Sommerville 2010).

As we stated above, this section focuses on the best practices to comprehend social requirements and user's needs to design better home care technology. Hence, to better frame how Requirement Engineering contributes to our goal, in this section

we draw particular attention on the contribution that Requirement Engineering delivers on the phase of requirement elicitation. This phase aims to define the social requirements by understanding the context of use of a hypothetic technology and the consequent needs and constraints of potential users, in order to acquire the knowledge that will shape the technology (Van Lamsweerde 2009). In other words, it focuses on acquiring knowledge about the current state of a system. An inadequate development of requirement elicitation may lead to several problems, such as delays in the project, resulting in failed expectations that may lead to a poor design of a software (Azadegan et al. 2013; Duarte et al. 2012; Geisser and Hildenbrand 2006; Van Lamsweerde 2009).

The elicitation phase is an iterative activity that encompasses various sources of data. This phase includes several research techniques, which are mainly qualitative, including interviews, focus groups, brainstorming and ethnography (Van Lamsweerde 2009; Geisser and Hildenbrand 2006; Nuseibeh and Easterbrook 2000). These techniques are aimed to collect information from three different domains: (a) information about the organizational context – such as stakeholder mapping, roles and conflicts – where the system will be implemented; (b) information about the general domain, in terms of organization structure and logistics aspects; and (c) information about the system as is – if any – that the stakeholders implemented to cope with the lack of available technologies to support their practices (Van Lamsweerde 2009).

The requirement elicitation can also be divided into two subcategories: (1) models focused on methodologies and techniques and (2) models focused on a high-level conception of elicitation. The former prescribe steps and techniques to adopt during the elicitation phase, whereas the latter are focused on assumptions on the domains to take into account during the elicitation (Hickey and Davis 2004).

The literature provides a few general examples. For instance, the CoRea (Geisser and Hildenbrand 2006) suggests to use meetings, brainstorming sessions or contextual inquiry (Van Lamsweerde 2009), which combines interviews and ethnographic observation to focus on the work activities of the users. Overall, these models are holistic, and they provide general guidelines, for elicitation and techniques, without targeting specific domains. Specifically, they do not target healthcare contexts (McGee-Lennon 2008). These models tend to address activities without an in-depth understanding of the professionals who perform them; this results in the risk of a poor comprehension of the context and, consequently, a poor definition of the social requirements.

The contextual knowledge of the professionals is essential during the elicitation of the social requirements, especially in a healthcare context. In this sense, requirement elicitation focuses on the role of the business analysts, which masters the techniques and enacts the requirements (Hickey and Davis 2004). However, to our best knowledge, the literature on Requirement Engineering does not completely valorise the role of the analyst and of the future users, which is paramount in the understanding of complex contexts, such as home care (Hickey and Davis 2004).

To summarize, we may claim that Requirement Engineering furnishes a structured approach that supports the software development and should allow a general-

ization of the outcome. Nonetheless, it fails to address the specificity of situated contexts – which require a deeper understanding of the practices in place – and does not fully consider the involvement of the analysts and the prospective users in the investigation.

10.3 Open Issues in Home Healthcare

Home care is a discipline that seeks the best practices to carry the care path of individuals/patients in their house. This discipline aims to let individuals/patients live in their home as long as possible, a place to which they are emotionally attached to (Bossen et al. 2013). Studies (Thomé et al. 2003; Bossen et al. 2013; Abowd et al. 2006; Mynatt et al. 2001; Christensen and Grönvall 2011) suggest that patients would gain additional benefits from being 'treated' within a familiar environment. The literature lists several benefits that home care may entail, fostering individuals/patients' compliance to care plans, improving individuals/patients' awareness about the care treatments, reducing hospitalizations, reducing costs of care and improving individuals/patients' quality of life (Rojas and Gagnon 2008).

Yet, to better understand this perspective, we need to introduce a new concept. Home care is strongly linked to the concept of 'continuity of care'. Continuity of care is an approach that proposes a change of paradigm by shifting from an overall primary care system – focused on an acute care organization – to a long-term home care system, which puts a regular and longitudinal path of care in the middle (Berwick 2009; Fatehi and Wootton 2012). This transition is perceived as a fundamental challenge that is changing the paradigm of the healthcare service organizations towards the engagement of a dense network of actors (Berwick 2009; Bodenheimer 2008).

Continuity of care was developed by focusing on the management of chronic conditions (Wagner et al. 1996). It deals with high organizational complexity, since home care involves a large number of care providers, and encompasses very diverse care medical locations (Wagner 2000). These issues lead to a greater demand of home care services in the developed countries, to allow families to deal with the care path within a "protected environment" (Bodenheimer 2008; Koch 2006; Postema et al. 2012). Continuity of care aims to establish a solid network of all the caregivers involved in the care path of an individual/patient, by also ensuring the coordination among the caregivers (Gröne and Garcia-Barbero 2001). The literature (Haggerty et al. 2003; Schoen et al. 2005) suggests that continuity of care enhances coordination among medical locations, such as central hospitals, local hospitals, specialist centres, clinics and individuals/patients' homes. Moreover, it provides a continuum of care, reshaping the care system by focusing on the needs of the individuals/patients.

Within this framework, Haggerty et al. (2003) proposed the concept of using three dimensions: (1) information continuity, which refers to the patients' sense of predictability, which is instilled by a coherent information sharing; (2) management

continuity, which refers to the patients' sense of safety that derives from responsive protocols and clear interactions between providers; and (3) relational continuity, which refers to the sense of predictability and coherence among relationships with the professionals.

Home care technologies can be an important resource towards reducing the risk of care fragmentation in home care services (Kripalani et al. 2007; Montenegro et al. 2011, Schoen et al. 2005). Care fragmentation is a phenomenon that leads to a fragmented understanding of a care reality, and it may derive from underestimating the illness of a patient (Stange 2009). This may lead individuals/patients and care professionals to an inconsistent understanding of the healthcare situation, and, subsequently, it would bring inefficiency, ineffectiveness, inequality, commoditization of health, de-professionalization and depersonalization (Stange 2009).

Studies (Wagner 2000; Gröne and Garcia-Barbero 2001; Stange 2009) suggest that technologies can hinder the care fragmentation by supporting the care management on three levels: (a) at the micro level, it can enhance information sharing and collaboration between patients and caregivers; (b) at the meso-level, it can foster mutual awareness and collaboration among heterogeneous caregivers; (c) at the macro level, it backs the supervising of an overall care service.

As an example, to better frame the home care domain, we can identify a macro area within which technology intervenes: "ageing in place" (Mynatt, Rogers 2001; Demiris et al. 2004; Beer and Takayama 2011). This area should support the independence of older adults, in order to leave them the possibility to cope with their health issues in their home. This area of research investigates on how to create a safe environment for older adults, while allowing family and professional caregivers to keep a hidden control of the older adults (Van Hoff et al. 2011). In this sense, the design of a suitable technology could ease the independence, but, in the same way, it could grant the possibility for the users to easily interact with the professional and family caregivers when needed or to allow the caregivers to coordinate and intervene when necessary (Van Hoff et al. 2011).

10.3.1 Home Care and the Technology: An Opaque Topic

Technology has an important role in supporting home care works and the management of home-based disease care programmes (Celler et al. 2003). However, there is an open issue on how the relation between technology and healthcare should be theoretically framed (Fatehi and Wootton 2012). Therefore, this domain seems opaque because of a proliferation of different technical definitions, which may appear unclear. To tackle this issue, we focus on how to better frame this domain by clarifying the different definitions and their corresponding perspectives.

The literature (Berwick 2009; Eysenbach 2000; Fatehi and Wootton 2012; Koch 2006; Silverman 2005) provides several examples of the terms that are generally used to describe technology-healthcare: telemedicine, E-health, telehealth, telehomecare, home-telecare, home-telehealth and telecare.

'Telemedicine', the oldest definition, was first used in 1972. It refers to systems used to remotely monitor patients. Basically, telemedicine exploits services of telecommunication to transmit medical information (Fatehi and Wootton 2012; Koch 2006; Silverman 2005). The other terms previously mentioned generally refer to systems to exchange medical data. Specifically, "E-health" concerns the management of information within health services, with particular attention to the role of the Internet (Eysenbach 2000). 'Telehealth' is conceived as a way to promote health, in terms of medical education, to raise awareness among patients (Celler et al. 2003, Koch 2006). 'Tele-homecare' and 'home-telecare' are used as synonyms. These terms refer to monitoring systems used to remotely control patients' vital signs, using interactive communication and biological assessments (Celler et al. 2003; Koch, 2006). 'Home-telehealth' encompasses a general use of telecommunication systems – with remote assistance – to exchange information about general health topics, including health education and care information (Koch 2006). 'Telecare' takes into account the importance of information sharing and its relative assessment, as well as the role of technology in managing a home care network built on human relations (Celler et al. 2003). Specifically, telecare is an interdisciplinary research field that focuses on collaborative technologies; it is related to "the ability to connect healthcare services across space and time, and provide treatments usually performed by physicians and nurses within hospitals or health care centers to citizens in their homes" (Bossen et al. 2013, p. 190). To our best knowledge, the literature seems to suggest that systems built on the principle of telecare may deliver several benefits to the users: a lower readmission rates, a more efficient collaboration among care providers and a higher collaboration of patients. From this perspective, telecare appears the term that is more comprehensive of the social complexity of home care. In this sense, it is recognized that there are needed technologies that are multi-user, multi-stakeholder, distributed, multimodal and dynamic, since this domain needs ad hoc technologies to manage the interrelation between places, healthcare providers, individuals, needs, sensibilities, data and information (McGee-Lennon 2008).

Nonetheless, from the literature we collected, we could identify two major features that characterize technological solutions for health contexts: (1) the medical data exchange and (2) the support of relations and care activities within the network of care (Milligan 2012).

Indeed, there seems to be a greater availability of papers concerning technical studies based on biological measurements and virtual visits (Fatehi and Wootton 2012; Silverman 2005; Koch 2006) and cost reduction (Delloitte 2016; Rojas and Gagnon 2008), compared to the availability of research on the role the technology may have in managing the human relations within home care contexts (such as Mynatt et al. 2001; Consolvo et al. 2004). Hence, the literature appears to focus more on data exchange and on the lack of universal data protocols to allow technologies to communicate by the same standard (Berwick 2009; Eysenbach 2000; Fatehi and Wootton 2012; Silverman 2005), whereas the literature on telecare sys-

tems to support collaboration in complex networks of healthcare seems to receive less attention (Fatehi and Wootton 2012; Silverman 2005; Koch 2006; Rojas and Gagnon 2008; Delloitte 2016). Hence, telemedicine calls for a greater multidisciplinary effort to accurately define social requirements (Celler et al. 2003; Fatehi and Wootton 2012; Silverman 2005), and we believe that this literature deserves greater attention in order to better comprehend how to define the social requirements (Bossen et al. 2013).

In particular, Koch (2006) identifies three common barriers related to home care services, which are the lack of standards and protocols, the lack of a shared framework of analysis and the lack of guidelines for the development of ad hoc solutions. In agreement with Koch (2006), a lack of guidelines and frameworks to support the definition of social requirements for home care is affecting the quality of the existing home care technologies. In relation to the design of home care technologies, more work needs to be done, both with the requirement approaches and with the knowledge about the healthcare's complexity.

10.3.2 Home Care from a Social Perspective

As we anticipated in the preceding section, a greater focus on technical factors, rather than on social needs and human' factors, would not allow for a precise comprehension of the social requirements. Indeed, there are issues that may limit the effectiveness of the design of technologies, for healthcare contexts, which deserve more attention. We identified three areas that summarize the recurring social issues in home care and that can hinder the design of effective technologies: (1) the coordination of caregivers involved in home care delivery, (2) the communication issues within stakeholders and (3) the complexity of the organizational setting of the healthcare sector.

10.3.2.1 Coordination Among Caregivers

The unpredictability of a medical condition does affect the physiological state of a patient, as well as care providers while assisting the patient itself.

Bodenheimer (2008, p. 1064) suggests that "given this level of complexity, the coordination of care among multiple independent providers becomes an enormous challenge". Several studies (Strauss 1984; Corbin and Strauss 1984; Bruni et al. 2007; Kripalani et al. 2007; Rojas and Gagnon 2008), carried with a peculiar attention to organizational issues, suggest that home care contexts encompass a large variety of care providers, each one with different expertise and skills, which could lead to several communication problems. Generally, there are many and very diverse formal caregivers involved in the care of a single patient. For instance, 47% of

patients in severe conditions are attended to by an average of four doctors and as many nurses (Schoen et al. 2005).

Within this framework, Weinberg et al. (2007, 2008) conceptualized care providers, distinguishing between formal and informal caregivers (or providers), but both perceived as co-producers of the care. The former are defined as experts, precisely healthcare professionals, whereas the latter are relatives who become 'experts' through a learn by doing approach, while assisting their loved ones. Formal and informal providers can also be distinguished by the tasks they perform, respectively, assistance during medical crisis and medical routine. Both can occur, unpredictably, due to the contingencies of the medical condition (Strauss 1984). Indeed, Corbin and Strauss (1984) stated "even the most routine and everyday tasks can vary in the manner in which, the time at which, and the person by whom they are performed, according to the tasks to be done and the contingencies that arise" (p. 228).

Often, the unpredictability of a medical condition can influence the care in two ways: (a) it can hinder the scheduling of medical examinations and, subsequently, the coordination among nurses, primary care physicians and secondary care physicians (Bodenheimer 2008); (b) it can affect the personal life of informal caregivers, who may face situations they are not formally prepared to (Corbin and Strauss 1984; Strauss 1984). In fact, "each change in illness conditions not only brings about changes in trajectory management but also affects the management of everyday life" (Corbin and Strauss 1984, p. 229).

10.3.2.2 Communication Issues

The second area concerns communication issues, which can be grouped into five main domains. Firstly, formal and informal caregivers have roles and expertise that do not facilitate the information exchange. On the one hand, informal caregivers manage the information on the medical situation (in terms of tests, exams, etc.) of a patient, and they need to share the information with the formal caregivers to coordinate the care. Patients and their families do not always have the right expertise to deal with medical issues which would require the assistance of professionals (Bodenheimer 2008; Kripalani et al. 2007; Schoen et al. 2005). Secondly, primary and secondary physicians struggle to coordinate because of the absence of communication protocols. The discharge letters historically refer to acute care protocols, and currently there is still a lack of communication protocols between physicians that are able to embrace the complexity of a long-term care plan for disease (Kripalani et al. 2007). Thirdly, there is a poor mutual involvement of primary and secondary physicians on the care plan and the discharge plan. Fourthly, the unpredictability of a medical situation often hinders the possibility to follow a strict schedule of treatments and medical appointments (Corbin and Strauss 1984). Finally, there is a the lack of universal data protocols to support information systems in communicating using the same standards.

Several studies (Kripalani et al. 2007; Silverman 2005; Fatehi and Wootton 2012) highlight the importance of these domains. In particular, poor communications and, consequently, a limited information flow lower the quality of home care services. As a consequence, this leads to discontinuity in the services and high rates of readmissions and relapses, creating the suspension of home care.

10.3.2.3 Organizational Complexity

The organizational complexity of the healthcare contexts is normally related to the variability of social dynamics, which are characterized by a strong individual know-how of the professionals.

Healthcare contexts do not generally have a fully formalized structure. In particular, there are soft and hard aspects that need to be considered (Kelman and Hong 2012). The former refers to the tangible aspects of an organization, such as the structure, the functions of each organizational level and the control protocols (Bruni et al. 2007), whereas the latter refers to the intangible dimensions of an organization, such as the culture, the common "language" and "symbols" and the shared values (Kelman and Hong 2012). These aspects are constantly renegotiated and readopted by the member of an organization (Weick 1969). Within these contexts, the individual skills and the organizational routines are conceived as the "building blocks of the organizational capability" (Dosi et al. 2008, p. 5). Accordingly, in healthcare contexts, individual skills and work practices are strongly related to soft aspects that are, by definition, difficult to handle (Kelman and Hong 2012; Bruni et al. 2007).

10.4 Discussion

The healthcare contexts and, specifically, home care contexts display many peculiarities that open the discussion on how to better address the requirements that should support the design of proper technologies. These contexts encompass a large variety of stakeholders, each one with different roles, tasks, expertise, experiences, expectations and needs. Therefore, as the literature suggests (Ackerman 2000; Whitworth 2009), social requirements are the nexus of the design of a technology, and, hence, inaccurate analysis of users' needs and contexts may affect the overall design process and the efficacy of a technology.

For this reason, we explained the importance of understanding the needs of the potential users, and we stressed the significance of the key points of attention that would deliver the terrain from which to build a consistent design process. Therefore, we presented a series of approaches that support the design of new technologies – CSCW, Participatory Design and Requirement Engineering – and we highlighted their strengths and weaknesses (summarized in Table 10.1).

Table 10.1 Summary of the approaches to the design of technologies for healthcare

Approach	Characteristics
CSCW	Focus on healthcare
	Focus on work practices
	Wide empirical contribution
	Flexible and situated
	Attention to social requirements
Participatory Design	Flexible and situated
	Attention to work dynamics and engagement
	Wide knowledge on techniques and empirical work
	Focus on epistemological issues of participation
Requirement Engineering	Macro approach that tend to formalization
	Offers macromodels
	Contribution focused on technical requirements

From this analysis, we can now affirm the importance of all of the approaches. However, each one delivers a contribution that can be enriched from one another, in order to create a novel approach able to better address and understand the social requirement a technology should be built on.

In particular, the great contribution of Requirement Engineering is to provide a groundwork for the definition of requirements useful for the development of a software. Requirement Engineering focuses, first, on how to employ the information that emerge during the requirement elicitation to later deliver them the following phases of the requirement definition, which are more on technical requirements. This approach is particularly useful to create generalizable models and knowledge. Yet, it lacks specific models for the requirement elicitation. The few existing models are considered holistic and inappropriate to valorise the specificity of the care contexts and the essential intuitions of business analysts (Hickey and Davis 2004).

CSCW and Participatory Design mainly focus on social requirements by understanding the needs of the future users. In this sense, they intend to comprehend the relations that users establish, the practices that users carry out and the contexts that users experience. These two approaches draw attention to epistemological problems, ethical dilemmas and empirical case studies, in order to address the main challenges in designing with and for users. For this reason, they do not deal with generic models on how to elicit requirements, but they are mainly engaged in flexible and situated design processes with the users. Computer-Supported Cooperative Work and Participatory Design rely on qualitative and narrative techniques and are less structured than Requirement Engineering. The effort of CSCW focuses more on collaborative technologies for working environments, and it draws particular attention to the care contexts, whereas Participatory Design focuses more on design challenges and on the engagement of users through a participative approach.

In summary, on the one hand, Requirement Engineering provides a structured model, which allows for a formalized way to grasp the social requirements. On the other hand, CSCW and Participatory Design furnish the right instruments and techniques to comprehend the situated needs of the people that will be the users of home care technologies.

To better understand the complexity of healthcare contexts, the literature we addressed in the previous paragraph highlights three types of issues that characterized the design of collaborative technologies for home care: (1) the lack of patient data and the lack of communication protocols among professionals, (2) the presence of coordination and organizational issues among the actors involved in the process of care and (3) the fluctuating and erratic nature of the healthcare. As we observed in the previous paragraphs, the literature on technologies and home care shows a lack of attention to the social concerns that may emerge within these three levels of issue. Conversely, studies appear to focus more on medical information, such as biological data and vital sign parameters. This seems to have brought a contribution to the field of telemedicine, rather than a contribution to support the organizational issues that lie behind the home care contexts.

Stange (2009) suggests that the continuities of care and home care are an open challenge that "requires a deeper than surface understanding of the problem" (p. 100). In fact, the network of home care is a mosaic where the caregivers co-produce together the care (Weinberg et al. 2007), and for this reason, it requires a major effort to raise awareness and collaboration among the professional and family caregivers. This is fundamental in order to create systems to allow for a transversal and continuous care (Haggerty et al. 2003).

Hence, we can affirm that the home care domain faces a series of challenges; it addresses issues on collaboration, heterogeneous actors, variability of the working practices and communication. These challenges limit the understanding of the social requirements. Therefore, the home care domain needs ad hoc guidelines and frameworks of analysis that can support the understanding of the social requirements, in order to address the interrelations among places, healthcare providers, individuals' needs and expectations, as well as data and information delivery, which characterize home care.

10.5 Conclusion

In this chapter, we introduced the key points of attention we believe are important to sustain how technologies for home care could be better addressed and designed. We tackled this issue by reviewing the main approaches that, nowadays, provide the tools to design information technologies, and we furthered the exploration of these approaches, in order to grasp the concepts that better served our scope. In addition, we proposed to merge the main features of these approaches to better understand the

key points that would lead to the understanding of the social requirements a technology should be built on. Finally, this whole introduction aimed to further the discussion on how to better address the challenges of designing technology for home care. We are aware about the vastness and complexity of this domain. Yet, we hope this discussion could open up the debate to other experts and professionals of the research fields we have taken into account, in order to bring together individuals with different backgrounds and thus to further the interdisciplinary discussion.

References

Abowd G et al (2006) Challenges and opportunities for collaboration technologies for chronic care management. The Human-Computer Interaction Consortium (HCIC 2006)

Ackerman MS (2000) The intellectual challenge of CSCW: the gap between social requirements and technical feasibility. Hum Comput Interact 15(2):179–203

Akama Y (2015) Being awake to ma: designing in between-ness as a way of becoming with. CoDesign 11(3–4):262–274

Azadegan A et al (2013) Collaborative requirements elicitation in facilitated collaboration: report from a case study. In: HICSS, 2013 46th Hawaii international conference on IEEE. pp 569–578

Bannon LJ, Schmidt K (1989) CSCW-four characters in search of a context. DAIMI Rep Ser 18(289)

Bannon L, Bjørn-Andersen N, Due-Thomsen B (1988) Computer support for cooperative work: an appraisal and critique. Eur Secur 88:297–303

Beer JM, Takayama L (2011) Mobile remote presence systems for older adults: acceptance, benefits, and concerns. In: Proceedings of the 6th international conference on Human-robot interaction. ACM, pp 19–26

Berwick DM (2009) What "patient-centered" should mean: confessions of an extremist. Health Aff 28(4):w555–w565

Bodenheimer T (2008, January 1) Coordinating care a perilous journey through the health care system. N Engl J Med 358(10):1064–1071

Boehm BW (1981) Software engineering economics, vol 197. Prentice-hall, Englewood Cliffs

Bossen C et al (2013) CareCoor: augmenting the coordination of cooperative home care work. Int J Med Inform 82(5):e189–e199

Bruni A, Fasol R, Gherardi S (2007) L'accesso ai servizi sanitari. Carocci, Roma

Celler BG, Lovell NH, Basilakis J (2003) Using information technology to improve the management of chronic disease. Med J Aust 179(5):242–246

Christensen LR, Grönvall E (2011) Challenges and opportunities for collaborative technologies for home care work. In: ECSCW 2011: Proceedings of the 12th ECSCW, Aarhus Denmark. Springer London, pp 61–80

Consolvo S, Roessler P, Shelton BE, LaMarca A, Schilit B, Bly S (2004) Technology for care networks of elders. IEEE Pervasive Comput 3(2):22–29

Corbin J, Strauss A (1984) Collaboration: couples working together to manage chronic illness. Image J Nurs Sch 16:109–115

Delaney KJ (2015) A freak accident this summer changed this top tech executive's approach to his business. Quarz. Retrieved August 2016 at: http://qz.com/548625/a-freak-accident-this-summer-changed-this-top-tech-executives-approach-to-his-business/

Delloitte (2016) 2016 Global Healthcare outlook. Battling costs while improving care. Retrieved December 2016 at: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Life-Sciences-Health-Care/gx-lshc-2016-health-care-outlook.pdf

Demiris G, Rantz MJ, Aud MA, Marek KD, Tyrer HW, Skubic M, Hussam AA (2004) Older adults' attitudes towards and perceptions of 'smart home'technologies: a pilot study. Med Inform Internet Med 29(2):87–94

Dosi G, Faillo M, Marengo L (2008) Organizational capabilities, patterns of knowledge accumulation and governance structures in business firms: an introduction. Organ Stud 29(8–9):1165–1185

Dourish P, Bellotti V (1992) Awareness and coordination in shared workspaces. In: Proceedings of the 1992 ACM conference on computer-supported cooperative work. ACM, pp 107–114

Duarte D, Farinha C, da Silva MM, da Silva AR (2012) Collaborative requirements elicitation with visualization techniques. In: Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE), 2012 IEEE 21st International Workshop on IEEE, pp 343–348

Ehn, P. (2008) Participation in design things. In: Proceedings of the tenth anniversary conference on participatory design 2008. Indiana University, pp 92–101

European Commission (2015) The ageing report: Economic and budgetary projections for the 28 eu member states (2013–2060). Retrieved from http://ec.europa.eu/economy_finance/publications/european_economy/ageing_report/index_en.htm

Eysenbach G (2000) Towards ethical guidelines for e-health. J Med Internet Res 2(1):e7

Fatehi F, Wootton R (2012) Telemedicine, telehealth or e-health? A bibliometric analysis of the trends in the use of these terms. J Telemed Telecare 18(8):460–464

Fernández-Ballesteros, R., Robine, J. M., Walker, A., & Kalache, A. (2013). Active aging: a global goal. Current gerontology and geriatrics research

Fitzpatrick G, Ellingsen G (2013) A review of 25 years of CSCW research in healthcare: contributions, challenges and future agendas. Comput Supported Coop Work (CSCW) 22(4–6):609–665

Geisser M, Hildenbrand T (2006) A method for collaborative requirements elicitation and decision-supported requirements analysis. Advanced Software Engineering: Expanding the Frontiers of Software Technology, pp 108–122

Gesano G, Heins F, Naldini A (2009) Regional Challenges in the perspective of 2020, Regional disparities and future challenges. ISMERI Europa

Gröne O, Garcia-Barbero M (2001) Integrated care. Int J Integr Care 1(2)

Haggerty JL, Reid RJ, Freeman GK, Starfield BH, Adair CE, McKendry R (2003) Continuity of care: a multidisciplinary review. BMJ 327(7425):1219–1221

Halskov K, Hansen NB (2015) The diversity of participatory design research practice at PDC 2002–2012. Int J Hum Comput Stud 74:81–92

Hickey AM, Davis AM (2004) A unified model of requirements elicitation. J Manag Inf Syst 20(4):65–84

Kelman S, Hong S (2012) "hard," "soft," or "tough love": what kinds of organizational culture promote successful performance in cross-organizational collaborations? Harvard Univ., John F. Kennedy School of Government, Cambridge, MA

Koch S (2006) Home telehealth—current state and future trends. Int J Med Inform 75(8):565–576

Kripalani S et al (2007) Deficits in communication and information transfer between hospital-based and primary care physicians: implications for patient safety and continuity of care. JAMA 297(8):831–841

Light A, Akama Y (2014) Structuring future social relations: the politics of care in participatory practice. In: Proceedings of the 13th PDC: Research Papers-Volume 1. ACM, pp 151–160

McGee-Lennon MR (2008) Requirements engineering for home care technology. In: Proceedings of the SIGCHI conference on human factors in computing systems. ACM, pp 1439–1442

Milligan C (2012) There's no place like home: place and care in an ageing society. Ashgate Publishing, Ltd, Farnham

Montenegro H et al (2011) Combating health care fragmentation through integrated health service delivery networks in the Americas:lessons learned. J Integr Care 19(5):5–16
Moran TP, Anderson RJ (1990, September) The workaday world as a paradigm for CSCW design. In: Proceedings of the 1990 ACM conference on computer-supported cooperative work. ACM, pp 381–393
Mynatt ED, Rogers WA (2001) Developing technology to support the functional independence of older adults. Ageing Int 27(1):24–41
Mynatt E et al (2001) Digital family portraits: supporting peace of mind for extended family members. In: Proceedings of SIGCHI conference on H-factors in computing systems 333–340 ACM
Nuseibeh B, Easterbrook S (2000) Requirements engineering: a roadmap. In: Proceedings of the conference on the future of software engineering 35–46. ACM
Postema TR et al (2012) Key factors influencing the implementation success of a home telecare application. Int J Med Inform 81(6):415–423
Rojas SV, Gagnon M-P (2008, November 01) A systematic review of the key indicators for assessing Telehomecare cost-effectiveness. Telemed E-Health 14:9,896–9,904
Schmidt K, Bannon L (1992) Taking CSCW seriously. Comput Supported Coop Work (CSCW) 1(1–2):7–40
Schoen C, Osborn R, Huynh PT, Doty M, Zapert K, Peugh J, Davis K (2005) Taking the pulse of health care systems: experiences of patients with health problems in six countries. HEALTH AFFAIRS-MILLWOOD VA THEN BETHESDA MA 24:W5
Silverman BG (2005) Intelligent paradigms for healthcare enterprises: systems thinking, vol 184. Springer Science & Business Media, Berlin
Simonsen J, Robertson T (eds) (2012) Routledge international handbook of participatory design. Routledge, London
Sommerville I (2010) Software engineering. Addison-Wesley, Harlow
Stange K (2009) The problem of fragmentation and the need for integrative solutions. Ann Fam Med 7(2):100–103
Strauss AL (1984) Chronic illness and the quality of life. Mosby, Saint Louis
Suchman LA, Trigg RH (1995, June) Understanding practice: video as a medium for reflection and design (excerpt). In: Human-computer interaction. Morgan Kaufmann Publishers Inc, San Mateo, pp 233–240
Thomé B, Dykes A-K, Hallberg IR (2003) Home care with regard to definition, care recipients, content and outcome: systematic literature review. J Clin Nurs 12(6):860–872
Van Hoof J et al (2011) Ageing-in-place with the use of ambient intelligence technology: perspectives of older users. Int J Med Inform 80(5):310–331
Van Lamsweerde A (2009) Requirements engineering: from system goals to UML models to software specifications. Wiley Publishing, Chichester
W.H.O (2008) The world report 2008: primary health care now more that ever
Wagner EH (2000) The role of patient care teams in chronic disease management. Br Med J 320(7234):569
Wagner EH et al (1996) Organizing care for patients with chronic illness. Milbank Q:511–544
Weick KEKE (1969) The social psychology of organizing (No. 04; HM131, W3.)
Weinberg DB et al (2007) Coordination between formal providers and informal caregivers. Health Care Manag Rev 32(2):140–149
Weinberg DB et al (2008) Impact of relational coordination on job satisfaction and quality outcomes: a study of nursing homes. Hum Resour Manag J 18(2):154–170
Whitworth B (2009) The social requirements of technical systems. Handbook of research on sociotechnical design and social networking systems 3
World Health Organization, and others (2002) Active ageing: a policy framework. Retrieved form http://www.who.int/ageing/publications/active_ageing/en/
Zave P, Jackson M (1997) Four dark corners of requirements engineering. ACM Trans Softw Eng Methodol (TOSEM) 6(1):1–30

Angela Di Fiore holds a degree in Sociology of Work, Organization and Information Systems and is currently a Ph.D. candidate in Information and Communication Technology at the Department of Computer Science and Information Engineering at the University of Trento. She is a member of InterAction Lab (http://interaction.disi.unitn.it/), a research group engaged in Interaction and Participatory Design bringing into dialogue different disciplinary perspectives, including the Computer Science, Psychology, Sociology, Anthropology, Design and the Arts. She works on Participatory Design and CSCW fields applied to Healthcare topics, having a specific focus on participants engagement, social requirements and phenomena of technology appropriation.

Francesco Ceschel holds a degree in Sociology of Work, Organization and Information Systems and is currently a Ph.D. candidate in Information and Communication Technology at the Department of Computer Science and Information Engineering at the University of Trento. He is a member of the LifeParticipation research group (http://lifeparticipation.org/). He works within the fields of Participatory Design and CSCW for de design of technology applied within the frameworks of active ageing and healthcare. He is also involved into the Rise-DREAM European project (https://sites.google.com/a/unitn.it/rise-dream/), for which he has been collaborating with the Universidad Costa Rica and the Universidad Católica Nuestra Señora de la Asunción.

Part VI
Privacy & Legal Requirements

Chapter 11
mHealth, Trust and the Security of Personal Data

Jennifer K. Lynch and Malcolm Fisk

Abstract The decentralisation of healthcare now extends, through the use of mobile technologies, beyond the home to people (patients) themselves. This heralds a revolution in the way people think about and use health and wellbeing services. This chapter explores the position in this changing landscape of mHealth, with particular reference to the use of apps. It gives specific attention to matters of trust, regulation and the security of personal data. These issues are highlighted as of especial importance considering the vulnerability of a high proportion of users of mHealth services.

Noted is both the rapid growth in the number of health apps publically available and the varied attention given by their creators to safeguarding personal data that may be stored or shared through their use. Trust, in relation to such matters, is suggested as being potentially increased through the use of standards that would address quality concerns. Nevertheless, there remains a responsibility for health professionals to understand and respond to the changes that are taking place – albeit in the context that they do not have 'mastery' over the mHealth technologies concerned. Finally, a framework is called for within which essential safeguards must be established in relation to trust in mHealth services and the security of personal data.

11.1 Introduction

Cristensen et al. (2009) noted that technologies in healthcare can be recognised as both enablers and disrupters. They are enablers because, amongst other things, they have helped in the development of precision medicine that is characterised by the better targeting of treatments and therapies. They are disrupters, because their increasing pervasiveness and lower cost open up part of the world of medicine to a

J.K. Lynch (✉)
University of Hertfordshire, Hatfield, UK
e-mail: j.lynch5@herts.ac.uk

M. Fisk
De Montfort University, Leicester, UK
e-mail: malcolm.fisk@dmu.ac.uk

H.R. Marston et al. (eds.), *Mobile e-Health*, Human–Computer Interaction Series,
DOI 10.1007/978-3-319-60672-9_11

wider public – this, in turn, undermining the long-held hegemony of the clinicians who saw themselves as having mastery over technologies in healthcare.

An element of the 'opening up' (p. 191) of medicine was pointed to by Cristensen et al. (2009) as a consequence of the advent of telemedicine, where the connectivity of devices enabled clinicians to share images and health data in a way that assists diagnoses and treatments. This same connectivity they saw as enabling a 'virtual decentralisation' (p. 101) of services. They failed, however, to extend the logic of their argument to points of care that were beyond the local clinic or to consider the way that mobile technologies would transform the way that people could (and would wish to) access health services.

In order to better consider the changes that are occurring, therefore, it must be recognised that the decentralisation pointed to by Cristensen et al. (2009) reaches not only the local clinic but also people's homes; and because of the availability of mobile devices (and subject to the availability of suitable communications networks), that decentralisation also reaches people (or patients) themselves – wherever they are located. What can be described as a 'technological turn' in health is not, therefore, just one that is instrumental in bringing greater efficiencies in health care; it is one that underpins a revolution in the way people think about and use health services. It means, furthermore, that it is necessary to think not narrowly in terms of 'telemedicine' (where health is seen more in medical terms) but rather in terms of 'telehealth' (where health can be seen equally in terms of lifestyles, prevention and well-being). Health, it is suggested, can no longer be seen as the preserve of the clinicians, rather it is more a matter for people themselves – whether or not they choose to carry the label of 'patient'. Telemedicine, with its clinical orientation, can be recognised, as affirmed by Darkins and Cary (2000), as a subset of tele*health* and rightly seen in relation to people's broader well-being.

In this context, the technological turn might now be usefully considered as a 'technological twist' where, although greater health efficiencies through the use of technologies are being achieved, the more important disruption is concerned with changes to the whole ethos and manner of health service provision. This will be reflected in further moves away from top-down forms of 'delivery' (a word that conveys, it is suggested, a somewhat one-way process) to a more inclusive manner of health service 'provision' (that allows for people to access health information and health services in new ways). The latter is facilitated through what is people's clearly greater access to technologies that help them in relation to their health and lifestyles – including through mHealth, the focus of this chapter.

The European Commission recognises telehealth and mHealth as part of digital health. The importance they attach to digital health is clear from both the eHealth Action Plan (European Commission 2012) and the extent of the European Commission's investment in relevant research projects (Emmanouilidou 2016). The pursuit of that digital health market is, therefore, reflected in the activities of technology developers and service providers within different European countries. In England, for instance, telehealth (including mHealth and also telecare – more oriented to social care) has been supported by special funds (Bennett and Humphries 2014). The National Health Service (NHS) has been responsible for the development

and promotion of an mHealth app, known as 'Flo' (or Florence, after Florence Nightingale), that is now widely used to help people to manage certain long-term conditions through text prompts and the exchange of information (Chambers et al. 2016). More broadly the NHS Mandate for 2013–2015[1] cites the objective of increasing technology use within the NHS as a priority – stating that in a digital age, the NHS should be at the forefront of new technologies that can help people manage their health and care (Department of Health 2013).

The World Health Organization (WHO 2011, p. 6) defines mHealth as 'medical and public health practice supported by mobile devices' and points to voice and text messaging, global positioning and 'more complex functionalities' (p. 1) that can be provided (ITU 2015). Crucially, the WHO has noted that, internationally, mHealth has begun to demonstrate an appeal beyond institutionally managed health provision. Hence, whilst the focus of many health-related apps (i.e. downloaded software for use on mobile devices) relates to the needs of chronically ill people, much else is targeted at a market embracing aspirational lifestyles and fitness (Research2Guidance 2015). Therefore, the WHO concludes that mHealth has relevance to people of all ages with varying health and well-being requirements. This understanding helps to legitimise the claims that mHealth 'is expected to effectively tackle the challenges healthcare systems are confronted with, thus leading to sustainable healthcare systems' (Emmanouilidou 2016, p. 4) and also has the potential to transform the healthcare industry 'into one that is personalized, participatory, preventive, and less expensive' (Malvey and Slovensky 2014, p. 1). This illustrates the potential for the extent of disruption as going much beyond that initially envisaged by Cristensen et al. (2009).

This is the backdrop to the way in which mHealth is emerging, resulting in opportunities – especially from the point of view of people wanting to take more responsibility for their health and to be able to access health services in new ways. But it also creates challenges for the structures, operational procedures and ethos of traditional health services. Impacting on these are privacy, safety, regulatory and ethico-legal questions considered in this chapter. We put forward recommendations regarding how some of the concerns about such matters might be addressed.

11.2 mHealth in Context

The growth of mHealth is rapid. It is manifested in the increased range of commercial products that are directly provided in or marketed to providers and consumers of health and social care. Included are products that can be considered under that broadest of umbrellas, the Internet of things (IoT) – linking to a futuristic phenomenon loosely defined by the UK government as one where 'everyday objects are

[1] Accessed at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/256497/13-15_mandate.pdf

connected to a network so that data can be shared' p. 6 – and seen as having the potential to deliver health benefits (Government Office for Science 2014). Indeed, Greenough (2015) noted that the growth of IoT is set to change the way governments, businesses and consumers interact with the physical world, including how healthcare, partly by means of mHealth, is provided.

This potential market growth is notable in a number of countries. Within Europe the mHealth research organisation – Research2Guidance – points to Denmark, Finland, the Netherlands, Sweden and in particular the UK as having the highest market readiness and most mature market conditions to enable mHealth companies' success (Research2Guidance 2016).[2] This was considered primarily to be due to the openness of clinicians to incorporate technology into their practice. Research by Xiaohui et al. (2014) points to mHealth transforming healthcare in the world's two largest economies – China and the USA. The WHO, meanwhile, supports initiatives in both developed and less developed countries through its 'Be He@lthy, Be Mobile' initiative. The programme, the WHO affirms, 'harnesses the power and reach of mobile phones to address the NCD [Non-communicable disease] risk factors by educating people to make healthier lifestyle choices' (World Health Organisation and ITU 2015, p. 3).

By the end of 2015, eight countries, extending from Costa Rica and Zambia to the UK, had funded initiatives under the programme, relating to smoking cessation, diabetes prevention and management and the setting up of public and preventative health monitoring platforms. The market in less developed countries has also been highlighted (ITU 2015) albeit, as noted by Clarke and Mars (2015), there are often difficulties because of shortcomings in the communications infrastructure. Having said this, Arie (2015) asserts that mHealth 'will be the future of healthcare in Africa' (p. 1), pointing to the thousands of mHealth pilot projects in low- and middle-income countries, concerned with needs as diverse as supporting pregnant women and reminding patients to take medication to recording children's arm circumferences as a way of monitoring malnutrition. In this context of emerging markets, expectations have been reported as high that mHealth will have a positive effect on the convenience, quality and cost of primary healthcare with PricewaterhouseCoopers (PWC 2012) finding patients in emerging markets having a greater awareness of mobile health technology than those in developed countries, being much more likely to already use mHealth and more interested in starting to use mHealth apps and services.

There is a link, furthermore, between mHealth and serious games (as discussed in Chaps. 6 (Duplaa et al.) and 7 (Marston et al.), with gamification noted as an element in 28% of health apps (Research2Guidance 2015)). Graafland et al. (2014) point, furthermore, to a growing literature on the role serious games can play in improving quality of life, health and well-being, albeit with outcomes that must await further research and evaluation. And Giunti et al. (2015) consider that serious games can be at least as effective as conventional approaches in improving the cognitive abilities

[2]The report can be accessed from http://research2guidance.com/the-5-countries-ranked-first-choice-for-starting-an-mhealth-business-in-the-eu/

of older people. The utilisation of serious games is, however, in its infancy, whilst the uptake of mHealth apps is now a worldwide phenomenon. Kamerow (2013), for instance, found over 100,000 health-related apps on Apple and Android smartphone platforms. Research2Guidance (2015) noted that Google Play and Apple App Store *each* offered almost 70,000 apps under the Health and Fitness and Medical categories.

It is, perhaps, unsurprising therefore that the surge in health-related apps has led to debate about the implications for user safety and privacy. Linked with this there has been calls for more attention on legal and regulatory frameworks (George et al. 2013; Gill et al. 2012; Kamerow 2013; Marston and Smith 2013; Vincent et al. 2015; Yasini and Marchand 2015). The safeguarding of individuals throughout their use of mHealth devices is, however, proving to be a far-reaching undertaking with divided views on whether a regulatory approach is either viable or desirable (Charani et al. 2014; Thompson and Brodsky 2013). What is less disputed are the potential threats to users that relate to the quality of the products in terms of the extent to which safeguards are included around content and privacy, the vulnerability to data breaches and other accidental, criminal or malicious activities, the implications of sharing data and, as pointed to by Degli Esposti (2014), 'dataveillance' (the systematic monitoring of people or groups, by means of personal data systems, in order to regulate or govern their behaviour).

11.3 Variable Quality in Health Applications

Critiques of mHealth regulation complain that it will stifle innovation, discourage investment and limit choice (Thompson and Brodsky 2013). However, the sheer volume of apps available has resulted in variable quality, both with regard to the validity and reliability of their content and the privacy safeguards ensured (Lewis and Wyatt 2014). The European Commission (2014) has noted that legislation is lacking and pointed out that it is 'not yet clear if and to what extent lifestyle and wellbeing apps could pose a risk to citizens' health' (p. 3). Standards that focus on mHealth are so far absent from the portfolios of the three European standards bodies CEN (the European Committee for Standardization), CENELEC (the European Committee for Electrotechnical Standardization) and ETSI (the European Telecommunications Standards Institute), though some other areas of telehealth are embraced. A mHealth subgroup of the European Commission's eHealth Network is, however, examining regulatory approaches. One of their reference points is the work undertaken by the British Standards Institution (BSI) in developing a PAS (Publicly Available Specification) code of practice for health and wellness apps. This does not, however, cover requirements for apps that are classified as medical devices (BSI 2015).

In the meantime, a number of international studies have raised concerns about risks to mHealth users. In a UK study of 111 chronic pain management apps[3], it was found that healthcare professionals had little involvement in app development or content, and the authors concluded that patients were at considerable risk of being misled due to spurious claims being made about pain relief through their use (Rosser and Eccleston 2011). Further studies in the USA, Australia and Norway have noted apps giving incorrect advice on disease management (Haffey et al. 2013; Wolf et al. 2013) or failing to properly take account of evidence-based recommendations (Chomutare et al. 2011).

Moreover, it has been suggested that it is not only patients who are at risk of being overwhelmed by incomplete or erroneous information. There are claims that some healthcare professionals who may have been enthusiastic adopters of apps to support clinical decision-making can be overwhelmed by the choice of apps available to them and may be misled by information and features that are fragmented across multiple apps (Charani et al. 2014; van Velsen et al. 2013). A 'critical evaluation framework' (Aljaber and Gordon 2016, p. 1) for mHealth education applications (aimed at both health professionals and patients) has been called for by Aljaber and Gordon (2016).

This raises inevitable questions about what happens when a patient or clinician acts on bad advice – who is liable? In Europe at least, there is no direct applicable liability legislation for eHealth *services* (as opposed to that which relates to hardware or software). This leaves a pressing need for the development or adoption of new frameworks involving legislation or standards that can clarify the responsibilities of the different parties (Andoulsi and Wilson 2013). In addition, there is an undoubted need to build people's digital literacy, by which they are better able to use mHealth. The accompanying gains in health literacy will, of course, enable them, when using mHealth (including apps), to make more informed decisions relating to their lifestyles and the sharing (or not) of their health and related personal data. Linked with this will be the extent to which users will be clear regarding their liability when using mHealth.

Part of the discussion around liability also relates to the way in which trust in mHealth applications is built. This is important both from the perspective of health professionals and individuals. It can be noted, for instance, that in a study of persons living with HIV in the USA, trust in the creators of mHealth apps, along with the perceived usefulness, ease of use and perceived risk, affected participants' intention to use them (Schnall et al. 2015). Alkhudairi and Pemberton (2016) reported on a range of factors affecting the acceptance of apps amongst Saudi diabetics and doctors, including concerns about the security of personal information.

With regard to the shortcomings of some apps, an analysis of the challenges related to the application of Android-based technology to fall detection found a complete absence of a reference framework to facilitate validation or comparisons in performance, as well as a lack of research evaluating the applicability of apps to fall detection (Casilari et al. 2015). By way of contrast, another study of an app for

[3]The official application stores for the following smartphone platforms were searched: iPhone, Android, Blackberry, Nokia/Symbian and Windows Mobile.

patients with diabetes, chronic obstructive pulmonary disease, hypertension and Asperger's syndrome found that the service, strongly supported by and developed in collaboration with clinicians, provided substantial reassurance – the overall service being viewed as positive with mutual benefits to patients and health staff (Cund et al. 2015). Yasini and Marchand (2015) reported that, in their analysis of apps with highly rated usability scores, the presence of related health professionals in the conception or development of the application, along with the use of reliable and valid bibliographic references to create content, was a key to their popularity.

Given the difficulties surrounding the need for regulation of mHealth, these studies suggest that trust and confidence in products or services could, in part, be built through standards, a key element of which is, of course, concerned with quality criteria. To achieve this, there have been suggestions for the standardisation of information through gateway apps that function as mobile portals leading users directly to high-demand health content or for a self-certification model to be put in place where developers register and distribute through a central platform (Lewis 2013; van Velsen et al. 2013).

Much of the responsibility rests with health professionals because it is necessary, in most instances, for health apps to demonstrably contribute to clinical outcomes. Clinicians may not, after all, still have 'mastery over technologies in healthcare', but they remain the custodians of expert knowledge around health. It follows that clinicians and other health professionals need to understand how people, including patients, are now incorporating technologies into their everyday lives. This is inevitably complex as mHealth is not only accessible worldwide but is being used in environments where external influences are varied and unpredictable. These environments and influences unavoidably bear on the user's experience – with consequences for safety, security and overall adoption (Albrecht 2013; Vincent et al. 2015).

11.4 Vulnerability to Data Breaches

If trust is a key component to the successful embedding of mHealth into how we manage our health and well-being, then having confidence in the security of the software (and hardware) in use is of paramount importance. Goodman (2016) reported that by 2013, more than 42,000 apps in Google Store had been found to contain 'spyware and information stealing Trojan programs' (Goodman 2016, p. 162). Lewis and Wyatt (2014) found that only 10% of the 600 health apps they investigated had a privacy policy. This is despite the fact that recommendations for ensuring data privacy and resistance to theft or hacking abound in the literature. These include the need for firewalls, encrypting data, password protection and high-security Wi-Fi connections (Gill et al. 2012).

Specifically in relation to devices issued by healthcare providers, further recommendations have been made to reduce opportunity for malicious access, such as enabling GPS functionality to trace mobile devices and downloading software to

monitor and record activity on devices (Charani et al. 2014; Gill et al. 2012). These clearly raise ethical issues about the amount of surveillance (e.g. the sharing of health and other personal data) that is warranted and acceptable to the user (whether it is an individual or health professional) and how informed consent is sought and maintained. Moreover, if devices are privately owned with health apps downloaded on the recommendation of a clinician, some safeguards may be difficult to enforce. The question once again turns to liability in the case of privacy and confidentiality breaches. There is a further point here about the ability of more vulnerable people to self-manage the security of their apps and hardware, particularly in a digital age where user agreements and requests for permission renewals are regularly updated (Batchelor et al. 2012).

11.5 Consent, Sharing Data and Dataveillance

The issue of consent is salient at all ages. However, despite the (correct) emphasis it is given to help legitimise people's usage of mHealth, it is clear that the fully *informed* consent of users in an ever-evolving digital environment can be little more than a pipe dream. This further signals the importance of trust and the need for frameworks of operation (for the providers of both technologies and services) that accord with ethically appropriate governance frameworks. The brutal truth, however, is that the extent of trust necessary will not be engendered unless data is effectively safeguarded, and in the arena of mHealth, it follows that much of that data is of a personal – and can be of a highly sensitive – nature.

Moreover, there are issues that relate to consent for people with diminished cognitive ability. Batchelor et al. (2012), for instance, have highlighted the ethico-legal responsibilities and duties of care towards technology users with dementia, as their capacity to make decisions changes. They called for updated data protection legislation to ensure that consent is obtained for specific data usage and for other rights to be recognised such as for people to be digitally forgotten (with data erased), once capacity to consent declines. However, how the 'burden' of expectation to be informed and thoughtful about protecting privacy and security may be threatening rather than empowering to those with dementia.

Even where dementia is not an issue, it is a matter of concern that in everyday interactions with digital technology, users are bombarded with requests to consent to updated agreements and terms and conditions. Yet, we all rarely engage in a meaningful way with these demands, and as noted by Goodman (2016), most terms and conditions remain unread. Where big data analytics are concerned, there is, furthermore, the added complication that the long-term usage of data is not predictable and therefore the provision of consent may be irrelevant and misleading (Tene and Polonetsky 2013).

A further issue relates to the ownership of personal data. In a context in which data is routinely shared through mobile devices, debates about ownership may

supersede the question of consent. Our view is that for health data (that relates to the body and its functioning, medication and therapies – current or past), ownership must reside with the person (patient), albeit entrusted to the providers of mHealth services. The ownership of any mHealth device that is used to store or transmit data, in this context, is, arguably, immaterial. Nevertheless, it has been asserted that a lack of seamless access to patient information across care pathways is a pressing issue for health professionals, leading to some using apps and mobile devices to work around the cumbersome bureaucratic systems with which they are confronted (Charani et al. 2014).

But how much data should be shared, and with whom? And what different rules might there be, e.g. for the purposes of research or for monitoring of public health and for the sharing of de-identifiable or anonymised data? We can note in this context that the process of de-identification of data has been called into question, particularly since a study of US census data found that in 87% of cases, citizens were uniquely identifiable from just three characteristics: birth date, zip code and gender (Sweeney 2000). On the positive side, Sweeney's study was a stimulus to the improvement of de-identification techniques, leading to a replication study finding that cases of unique identification using those data categories had dropped significantly a few years later (Golle 2006). Others have claimed that fears about de-identification have been exaggerated as the risks are much lower than presented in either of the above studies, *if* strong de-identification techniques are employed (Cavoukian and Castro 2014).

However, this risk of being identified is not negligible and increases if additional datasets can be cross-referenced. For example, providers of wearable fitness trackers have been criticised in a recent report by Canadian research organisation for exposing device wearers to long-term tracking of their location through the emitting of persistent unique identifiers (Hilts et al. 2016). It is claimed, for example, that this practice can be used by shopping malls that have Bluetooth beacons that can track and profile devices in order to create targeted mobile advertising. Furthermore, the research in question found that certain applications could be exploited to create fake records – a pertinent finding when fitness tracker data has been used in court cases and in assessments of health and life insurance eligibility (Lupton 2016). This brings the debate back to questions of trust (Has my data been strongly de-identified? How do I know what is happening to my data? Have I given consent for my data to be used or shared in this way?).

Degli Esposti (2014) has probed these issues by looking at what has been termed 'dataveillance'. She provides examples of how data are collected (e.g. through store cards) and acted upon (e.g. with targeted promotions) to demonstrate that even when individuals are not identifiable, they may still be reachable. This makes the notion of anonymity less meaningful – at least for everyday transactions. Having said this, such transactions may be laden with health-related information where goods or services relating to lifestyles, illness, disability, etc. are accessed or purchased. One response to this has been the promotion of individuals taking greater control by setting up a personal data store that allows users to hold verified information about themselves in an encrypted and secure way. Mydex provides one such

example (see https://mydex.org), as does the Hub of All Things (HAT) project, which claims to allow individuals to contextualise their data to help them make decisions and allow them to control how they interact on the Internet and manage relationships with corporations (hubofallthings.com). Therefore, part of the solution may well lie in the promotion of products and services where data is strictly held on or near to the person, rather than communicated to a remote server.

11.6 Conclusions

In this chapter we have noted how the development and disruptive effect of mHealth has the potential to transform healthcare. We have indicated the way it is being harnessed by people for a range of health and lifestyle needs. But we have also pointed to a number of possible risks for mHealth that relate to privacy, safety and, crucially, trust, which need to be addressed if the potential is to be realised.

What becomes clear is that the absence of an ethico-legal framework is hindering uptake. Such a framework, we consider, should be prioritised and embedded in legislative frameworks and/or standards, with robust safeguards on personal privacy. Alongside legislation, there is also a need for a wide-ranging approach to improving people's knowledge and health literacy and consequently their ability to take advantage of the opportunity that mHealth (and related telehealth initiatives) affords. Linked with this are the need to tackle the pivotal issues of consent, trust and control (particularly in relation to questions about personal data); the uncertainty around ownership of personal (including health) data; and to combat the risks around privacy and data sharing. There is some urgency that attaches to this agenda if the benefits of mHealth are to be harnessed – most importantly with regard to its capacity to help people take more responsibility for their health and health behaviours.

References

Albrecht U-V (2013) Transparency of health-apps for trust and decision making. J Med Internet Res 15(12):e277. https://doi.org/10.2196/jmir.2981

Aljaber T, Gordon N (2016) Evaluation of mobile health education applications for health professionals and patients. In: Multi conference on computer science and information systems: eHealth 2016, Funchal, Madeira, pp 107–114

Alkhudairi B, Pemberton L (2016). Factors affecting the acceptance of mHealth technology by Saudi diabetics and doctors. In: Multi conference on computer science and information systems: eHealth 2016, Funchal, Madeira, pp 199–202

Andoulsi I, Wilson PP (2013) Understanding liability in eHealth: towards greater clarity at European Union level. In: George C, Whitehouse D, & Duquenoy P (eds) Springer Berlin Heidelberg, Berlin/Heidelberg. Retrieved from http://link.springer.com/10.1007/978-3-642-22474-4

Arie S (2015) Can mobile phones transform healthcare in low and middle income countries? BMJ 350(apr22 20):h1975–h1975. https://doi.org/10.1136/bmj.h1975

Batchelor R, Bobrowicz A, Mackenzie R, Milne A (2012) Challenges of ethical and legal responsibilities when technologies' uses and users change: social networking sites, decision-making capacity and dementia. Ethics Inf Technol 14(2):99–108. https://doi.org/10.1007/s10676-012-9286-x

Bennett L, Humphries R (2014) Making best use of the better care fund. Spending to save? London

BSI (2015) PAS 277:2015 health and wellness apps. Quality criteria across the life cycle. Code of practice. Retrieved from http://shop.bsigroup.com/forms/PASs/PAS-2772015/

Casilari E, Luque R, Morón M-J (2015) Analysis of android device-based solutions for fall detection. Sensors 15(8):17827–17894. https://doi.org/10.3390/s150817827

Cavoukian A, Castro D (2014) Big data and innovation, setting the record straight: de-identification does work. Ontario, Canada. Retrieved from http://www2.itif.org/2014-big-data-deidentification.pdf

Chambers R, Schmid M, Birch-jones J (2016) Digital healthcare: the essential guide. Otmoor Publishing, Oxford

Charani E, Castro-Sánchez E, Moore LS, Holmes A (2014) Do smartphone applications in healthcare require a governance and legal framework? It depends on the application! BMC Med 12(1):29. https://doi.org/10.1186/1741-7015-12-29

Chomutare T, Fernandez-Luque L, Årsand E, Hartvigsen G (2011) Features of mobile diabetes applications: review of the literature and analysis of current applications compared against evidence-based guidelines. J Med Internet Res 13(3):e65. https://doi.org/10.2196/jmir.1874

Clarke M, Mars M (2015) An investigation into the use of 3G mobile communications to provide Telehealth Services in Rural KwaZulu-Natal. Telemed E-Health 21(2):115–119. https://doi.org/10.1089/tmj.2014.0079

Cristensen CM, Grossmans JH, Hwang JH (2009) The Innovator's prescription: a disruptive solution for health care. McGraw-Hill Education, New York

Cund A, Connolly P, Birch-Jones J, Kay M (2015) Self-management: keeping it simple with "Flo". Nurs Res Rev 49. https://doi.org/10.2147/NRR.S72791

Darkins AW, Cary MA (2000) Telemedicine and telehealth: principles, policies, performances and pitfalls. SpringerReference. Springer, Berlin/Heidelberg. https://doi.org/10.1007/SpringerReference_84830

Degli Esposti S (2014) When big data meets dataveillance: the hidden side of analytics. Surveill Soc 12(2):209–225. Retrieved from http://library.queensu.ca/ojs/index.php/surveillance-and-society/article/view/analytics/analytic

Department of Health (2013) The mandate. A mandate from the Government to the NHS Commissioning Board: April 2013 to March 2015. London

Emmanouilidou M (2016) The status of mHealth in Europe and a review of regulative challenges. In: Multi conference on computer science and information systems: eHealth 2016. Funchal, Madeira, pp 203–206

European Commission. eHealth Action Plan 2012–2020 – Innovative healthcare for the 21st century (2012) Brussels

European Commission. COMMISSION STAFF WORKING DOCUMENT on the existing EU legal framework applicable to lifestyle and wellbeing apps (2014) Brussels, 10.4.2014 SWD(2014) 135 final

George C, Whitehouse D, Duquenoy P (2013). Assessing legal, ethical and governance challenges in eHealth. In: George C, Whitehouse D, Duquenoy P (eds) Springer, Berlin/Heidelberg, pp 3–22. Retrieved from http://link.springer.com/10.1007/978-3-642-22474-4

Gill P, Kamath A, Gill TS (2012) Distraction: an assessment of smartphone usage in health care work settings. Risk Manag Healthcare Policy 105. https://doi.org/10.2147/RMHP.S34813

Giunti G, Baum A, Giunta D, Plazzotta F, Benitez S, Gómez A, … González Bernaldo de Quiros F (2015) Serious games: a concise overview on what they are and their potential applications to healthcare. In: Sarkar IN, Georgiou A, Mazzoncini de Azevedo Marques P (eds) MEDINFO 2015: eHealth-enabled health: proceedings of the 15th world congress on health and biomedical informatics. IOS Press, Sao Paulo, pp 386–390. https://doi.org/10.3233/978-1-61499-564-7-386

Golle P (2006) Revisiting the uniqueness of simple demographics in the US population. Alexandria, Virginia. Retrieved from http://crypto.stanford.edu/~pgolle/papers/census.pdf

Goodman M (2016) Future crimes: inside the digital underground and the battle for our connected world. Anchor Books, Toronto

Government Office for Science (2014) The internet of things: making the most of the second digital revolution. A report by the UK Government Chief Scientific Adviser, London

Graafland M, Dankbaar M, Mert A, Lagro J, De Wit-Zuurendonk L, Schuit S et al (2014) How to systematically assess serious games applied to health care. JMIR Serious Games 2(2):e11. https://doi.org/10.2196/games.3825

Greenough J (2015) How the "Internet of Things" will impact consumers, businesses, and governments in 2016 and beyond. Retrieved January 8, 2016, from http://www.techinsider.io/how-the-internet-of-things-market-will-grow-2014-10

Haffey F, Brady RRW, Maxwell S (2013) A comparison of the reliability of smartphone apps for opioid conversion. Drug Saf 36(2):111–117. https://doi.org/10.1007/s40264-013-0015-0

Hilts A, Parsons C, Knockel J (2016) Every step you fake: a comparative analysis of fitness tracker privacy and security. Retrieved from https://openeffect.ca/reports/Every_Step_You_Fake.pdf

ITU (2015) m-Powering development initiative: a report by the m-Powering development initiative advisory board. Retrieved from http://www.itu.int/en/ITU-D/Initiatives/m-Powering/Documents/m-PoweringDevelopmentInitiative_Report2015.pdf

Kamerow D (2013) Regulating medical apps: which ones and how much? BMJ 347(oct08 4), f6009–f6009. https://doi.org/10.1136/bmj.f6009

Lewis TL (2013) A systematic self-certification model for mobile medical apps. J Med Internet Res 15(4):e89. https://doi.org/10.2196/jmir.2446

Lewis TL, Wyatt JC (2014) mHealth and mobile medical apps: a framework to assess risk and promote safer use. J Med Internet Res 16(9):e210. https://doi.org/10.2196/jmir.3133

Lupton D (2016) Digital health technologies and digital data: new ways of monitoring, measuring and Commodifying human embodiment, health and illness. In: Xavier Olleros F, Zhegu M (eds) Edward Elgar Pub, Northampton. https://doi.org/10.1017/CBO9781107415324.004

Malvey D, Slovensky DJ (2014) mHealth: transforming healthcare. Springer, New York

Marston HR, Smith ST (2013) Understanding the digital game classification system: a review of the current classification system and its implications for use within games for health. In: Holzinger A, Ziefle M, Hitz M, Debevc M (eds) Springer, Berlin, pp 314–331

PWC (2012) Emerging mHealth: Paths for growth. Retrieved from www.pwc.com/mhealth

Research2Guidance (2015) mHealth app developer economics 2015: the current status and trends of the mHealth app market. Retrieved from http://research2guidance.com/r2g/r2g-mHealth-App-Developer-Economics-2015.pdf

Research2Guidance (2016) mHealth app developer economics 2016. Retrieved from http://research2guidance.com/r2g/r2g-mHealth-App-Developer-Economics-2016.pdf

Rosser BA, Eccleston C (2011) Smartphone applications for pain management. J Telemed Telecare 17(6):308–312. https://doi.org/10.1258/jtt.2011.101102

Schnall R, Higgins T, Brown W, Carballo-Dieguez A, Bakken S (2015) Trust, perceived risk, perceived ease of use and perceived usefulness as factors related to mHealth technology use. Stud Health Technol Inform 216:467–471. https://doi.org/10.3233/978-1-61499-564-7-467

Sweeney L (2000) Uniqueness of simple demographics i nthe U.S. Population. Pittsburgh

Tene O, Polonetsky J (2013) Big data for all: privacy and user control in the age of analytics. Northwestern J Technol Intellect Property 11(5): xxvii–274. Retrieved from file:///C:/Users/Admin/Downloads/11NwJTechIntellPropxxvii.pdf

Thompson BM, Brodsky I (2013) Should the FDA regulate mobile medical apps? BMJ 347(aug29 1), f5211–f5211. https://doi.org/10.1136/bmj.f5211

van Velsen L, Beaujean DJ, van Gemert-Pijnen JE (2013) Why mobile health app overload drives us crazy, and how to restore the sanity. BMC Med Inform Decis Mak 13(1):23. https://doi.org/10.1186/1472-6947-13-23

Vincent CJ, Niezen G, O'Kane AA, Stawarz K (2015) Can standards and regulations keep up with health technology? JMIR mHealth uHealth 3(2):e64. https://doi.org/10.2196/mhealth.3918

WHO (2011) mHealth: new horizons for health through mobile technologies. Global Observatory for eHealth series, vol 3. Retrieved from http://www.who.int/goe/publications/goe_mhealth_web.pdf

Wolf JA, Moreau JF, Akilov O, Patton T, English JC, Ho J, Ferris LK (2013) Diagnostic inaccuracy of smartphone applications for melanoma detection. JAMA Dermatol 149(4):422. https://doi.org/10.1001/jamadermatol.2013.2382

World Health Organisation, & ITU (2015) BE HE@LTHY BE MOBILE: Annual Report January 2015 to December 2015. Retrieved from http://www.itu.int/en/ITU-D/ICT-Applications/eHEALTH/Be_healthy/Documents/BHBM-AnnualReport-2015.pdf

Xiaohui Y, Han H, Jiadong D, Liurong W, Cheng L, Xueli Z, … Bleiberg J (2014) mHealth in China and the United States: how mobile technology is transforming healthcare in the world's two largest economies. Retrieved from https://www.brookings.edu/wp-content/uploads/2016/06/mHealth_finalx.pdf

Yasini M, Marchand G (2015) Mobile health applications, in the absence of an authentic regulation, does the usability score correlate with a better medical reliability? MEDINFO 2015: eHealth-Enabled Health: Proceedings of the 15th world congress on health and biomedical informatics, 127–131. https://doi.org/10.3233/978-1-61499-564-7-127

Dr Jennifer K. Lynch's research explores the use of technology in support for older people with complex health conditions. Her fellowship at the University of Hertfordshire focuses particularly on the health and social care needs of people living with dementia and their carers. Jennifer's PhD investigated the policy discourse and multi-agency working in the provision of telecare and telehealth services in the UK. She has an enduring interest in the ethical debate surrounding the role of technology in enhancing (or not) the autonomy and independence of older people living in the community. Jennifer currently leads a case study in the Wellcome Trust funded programme Studies in Co-creating Assisted Living Solutions (SCALS), which looks at organisational barriers to the creative and adaptive use of assisted living technologies by older people with chronic illness and the people who support them.

Dr Malcolm Fisk is widely recognised for his work on the experience of people, especially in older age, regarding their access and use of technologies and services for health and well-being. He leads the European Commission funded PROGRESSIVE project that addresses 'standards around ICT for active and healthy ageing'; and as Director of the Telehealth Quality Group he is actively engaged in supporting the development of quality standards for telehealth services. Malcolm's other roles include being an expert advisor for ANEC: The European Consumer Voice on Standardisation; and being a member of European CEN Committees concerned with both health and care services. He is also a member of a Quality Standards Advisory Committee for NICE, the National Institute for Health and Care Excellence. Previously Malcolm was appointed by the Welsh Government to Chair the National Partnership Forum for Older People and subsequently to provide expert advice to them relating to poverty and inequality; and the housing and related support needs of older people.

Chapter 12
Are mHealth Apps Safe? The Intended Purpose Rule, Its Shortcomings and the Regulatory Options Under the EU Medical Device Framework

Eugenio Mantovani and Pedro Cristobal Bocos

Abstract This chapter discusses the legality of operating commercially available applications or 'apps' for medical purposes in Europe. The meticulous certification process established in the Medical Device Directive (MDD) is seldom applied to mHealth apps. This is due to the application of the concept of "intended purpose", which allows app developers to create apps that are analogous to medical devices (i.e. having similar functions) but, because they have not been intended by their manufacturers to attain a medical purpose, they do not need to satisfy the stringent safety checks foreseen in the MDD. The chapter highlights two vulnerabilities of this regulatory framework, concerning the reliability of the apps and the traceability of "bad apps". In response to these concerns, the EU has taken a mixed approach-combining top down regulation with stakeholders' participation and "self-assessment". A comparison with the regulation of borderline apps in the United States allows the authors to make a recommendation for future research and policies concerning mHealth apps in Europe.

This chapter discusses the legality of operating commercially available applications or "apps" for medical purposes. This chapter observes how the meticulous certification process established in the Medical Device Directive (MDD) is seldom applied to mHealth apps. This is the result of the application of the concept of "intended purpose". This concept allows app developers to create apps that analogous to medical devices (i.e. having similar functions), but, because they have not been intended by their manufacturers to attain a medical purpose, they do not need to satisfy the stringent safety checks foreseen in the MDD. With the aid of concrete examples, this chapter highlights two gaps in the regulation of mHealth apps, concerning the

E. Mantovani (✉) • P.C. Bocos
LSTS – VUB, Brussels, Belgium
e-mail: emantova@vub.ac.be

H.R. Marston et al. (eds.), *Mobile e-Health*, Human–Computer Interaction Series,
DOI 10.1007/978-3-319-60672-9_12

reliability of the apps and the traceability of "bad apps". In response to these concerns, the EU has taken a mixed approach combining top-down regulation with stakeholders' participation and "self-assessment". A comparison with the regulation of borderline apps in the USA allows the authors to make a recommendation for future research and policies concerning mHealth apps.

12.1 Introduction

Mobile health technologies (MHTs or mHealth) are extending beyond the precincts of hospitals and health-care services into a growing market of applications (apps) for well-being or lifestyle. There are today over 100,000 mHealth apps available on the market that work in combination with smartphones, tablets, and wearables (European Commission 2016a).

As with any technological development, mHealth is laden with uncertainties, ambiguities, and interpretative flexibility in terms of meanings, values, and cognitive frames associated with artefacts (Bijker 2010, p. 68). Regulation, which we take as "the intentional activity of attempting to control, order or influence the behaviour of others" (Black 2002, p. 1), is one of the elements influencing this interpretative flexibility. This holds particularly true for safety regulations, which put constraints on developers of mHealth apps.

In Europe, the centrepiece legislation with regard to the safety of medical devices is the Medical Device Directive (MDD). This directive, part of the medical device framework (MDF), amended in 2007, and currently undergoing a general revision, explicitly includes in its scope software that works in combination with mobile devices, known as "applications" or "apps".

Increasingly many mHealth apps that are presently commercially available are, in fact, not considered as medical devices (Medical Device and Diagnosis Industry 2015), but are introduced into the market as simple software. As such, the safety of several mHealth apps available in the EU today is gaged against the general requirements for information society services, and not against the more stringent, as we will see, requirements for medical devices. This chapter puts into question this state of affairs.

Section one provides a definition of mHealth and, with the aid of a scenario, highlights the importance of guaranteeing the safety of mHealth apps. Section two describes the legislative framework, pausing on the definition of medical device, the "intended purpose" rule, the essential requirements that app developers need fulfil, and the control and supervisory mechanisms that are in place. Recognising that many mHealth apps enter the market without going through the safety checks of the MDD, section three discusses two problems: the reliability of apps and the traceability of "bad" apps. Section four pauses on the EU regulatory initiatives adopted to address the vulnerabilities of the so-called borderline apps. Eventually, section five looks at relevant aspects of the US system that departs from the EU.

12.1.1 Navigating Daily Life with Safe mHealth Apps

The International Telecommunication Union (ITU) defines mHealth as "all available services for delivering care or medical information using mobile equipment and networks" (International Telecommunications Union 2014). For the European Commission, the term refers to "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices"(European Commission 2014a, p. 3).

From a technical point of view, mHealth "apps" are software programs that run on mobile devices (hardware) such as smartphones, tablets, smartwatches (Huckvale et al. 2015). These pieces of software process data collected by sensors, such as accelerometers, gyroscopes, ambient light sensors, GPS, cameras, and multitouch screen, which are embedded in the (hardware) mobile devices. The flexibility offered by a smart device allows applications (software) to collect and process information for an astonishing range of purposes (Article 29 Data Protection Working Party 2013, p. 2).

A non-exhaustive list of mHealth apps include apps for patient and carer decision aids, such as the "Chronic Obstructive Pulmonary Disease (COPD) – NHS Decision Aid" app that helps people make a decision about treatment choices (Google Play 2013); apps for self-management, such as the "Self-help for Anxiety Management" app, which offers a range of self-help methods to manage anxiety (Itunes 2015); apps for treatment recommendation, such as the "Micromedex" app, which delivers proper drug dosage and medicine recommendations (DigitalTrends 2016); apps for monitoring, accessing, and editing electronic health records such as the "MyChart" app, which provides access to medical records "through the phone at any time" (DigitalTrends 2016); communication apps such as "Telemed", which enable patients to send images of their skin, eyes, or body (Google Play 2016); the "UpToDate" app, which "tracks medical advancements and news" (DigitalTrends 2016), and so on and so forth.

The uptake of mHealth has been dramatic in the last years. In the USA, a third of physicians say they have recommended an app to a patient (IHS Report 2013); 7 in 10 U.S. adults admit to routinely using one or more health tracking apps (Pew Research 2013). In Europe, the European Commission estimates that over 100,000 mHealth apps are currently available on the market (European Commission 2016a). Of these, approximately 70% target the wellness and fitness sectors, and 30% of apps are specifically designed for health professionals (Deloitte 2012).

It is not only the quantity of mHealth apps that has attracted attention. Mobile health, it has been said, has captured our collective imagination (Cortez 2014). Observers argue that mobile health technologies will "revolutionise" the way we deliver, consume, measure, and pay for health care (Prainsack 2014; Hanlon and Thiel 2016; Cortez 2014). In literature, while some authors discuss the impact on health-care services and systems, others focus on how technology meddles with ordinary, routine life.

In the first chapter of her recent book, legal scholar Mireille Hildebrandt depicts in a scenario the life of a young mother, rampant professional, Diana, and of her frail old father, Jacob. Both navigate their day accompanied by a personal digital assistant (PDAs) (Hildebrandt 2015). The mobile device of old, frail Jacob (in the book the PDA is embodied in a robot) is programmed to:

> Exchange information with similar devices from the same service provider, and with a number of healthcare service providers […]: Jacob's family doctor, the medical specialists who treat his various conditions, the insurance that covers the cost, the pharmacies that supply his medications, and the local nursing centre that provides him with hands-on medical care. (Hildebrandt 2015, p. 6)

Jacob's PDA is able to detect a serious harm from a mild symptom that is, statistically speaking, to be expected. The application that runs on Jacob's device has been designed to set off an alarm only in case a certain condition threshold is crossed. Interestingly, Hildebrandt imagines that the decision of the PDA as to whether or not to send out an alert depends on the input that is provided by another app running on the PDA. This other app has been designed to learn about old Jacob's vision of the world, values, and, given his advanced age, his attitudes towards end of life decisions. In the scenario, the PDA detects an anomaly in Jacob's biometric parameters but, based on previous preferences, decides not to alert him or anyone else. Three days later Jacob dies of a stroke.

As Hildebrandt points out, the scenario is not farfetched. Mobile technologies are already allowed to make invisible inferences of risks and preferences (e.g. playing the right tune for the morning jog, suggesting what to eat, and when to train) or make choices on our behalf (e.g. respecting our values and don't disturb me decisions). The story of Jacob suggests several ethical, societal, and legal questions that are emerging around mHealth: the impact on patients' autonomy, the boundaries of private life and family life, the responsibility of carers, the confidentiality of medical records, the right to be and not to be informed, etc. (Prainsack 2014).

This contribution departs from the sobering recognition that the scenario portrayed above may never see the light, mHealth apps stop being downloaded and sold, if the technology is not safe enough (European Commission 2014b). Take Jacob's mobile device: Will the app send an alarm off when the agreed threshold is reached? Is the software assessing Jacob's value accurately? What happens in the case of conflict between two opposed courses of action, e.g. alert the relatives or not? In the EU, the decision as to whether apps for mobile phones are safe to be used and marketed depends on a certification system regulated by the EU medical device framework. Given that Jacob's and most mHealth scenarios are likely to employ medical software, this framework is of cardinal importance.

12.1.2 Safety of mHealth Apps in the EU Medical Device Legal Framework

12.1.2.1 Introduction

In Europe, the organisation of health care is firmly in the hands of the Member States. After the Maastricht Treaty of 1992, however, the EU introduced a medical device framework (MDF) laying down common rules for the safety of medical devices produced and commercialised in the internal market. The 2009 Treaty of the Functioning of the EU (TFEU) recognises this EU's exclusive competence, sanctioning it in competence to legislate in "high standards of quality and safety for medicinal products and devices for medical use" (European Union 2012, p. 122).

The MDF, which is currently undergoing a process of reform (European Commission 2012a), consists of three directives: the Medical Devices Directive (MDD) 93/42/EEC (European Communities 1993), amended in 2007 by Directive 2007/47/EC (European Union 2007), the Active Implantable Medical Devices Directive (AIMD) 90/385/EEC (European Communities 1990), and the In Vitro Diagnostic Medical Devices Directive (IVDMD) 98/79/EEC (European Communities 1998).

While the AIMD and the IVDMD apply to specific technologies, the MDD is applicable to most medical devices, including software (Callens 2010). Because of the main theme of this chapter, only the MDD is considered. In this chapter, the expressions "MDF" and "MDD" are used exchangeably to refer to the framework described below.

12.1.2.2 The Legislative Framework

Directive 93/42/EEC, the Medical Device Directive (MDD), harmonises national provisions for the safety and health protection of patients, users, and other persons with regard to the use of medical devices. The MDD covers medical devices, from simple bandages, sticking plasters to sophisticated equipment and information technology tools. The legislative regime introduces a classification schemes geared on the risks that a device poses to the human body. The directive puts developers under the obligation to respect a series of essential requirements and documentary procedures. National bodies verify this process.

Importantly for mHealth, a series of guidelines complement the MDD clarifying some of the obscurities of the directive and its implementation. The European Commission's MEDDEV guidelines (medical devices guidance documents) (last amendment 2016b) and the guidelines on assessment of the reliability of mobile health applications (2016c) are of particular relevance for the regulation of mHealth apps and will be broached below.

12.1.2.3 Definition of Medical Device

The basic idea behind the MDD is that all computer programs that meet the definition of a medical device must comply with the MDD (Callens 2010). According to article 1, point 2, letter a, of Directive 93/42/EEC a medical device is:

> Any instrument, apparatus, appliance, software, material or other article, whether used alone or in combination, including the software intended by its manufacturer to be used specifically for diagnostic and/or therapeutic purposes and necessary for its proper application. Such a device should be "intended by its manufacturer.

for a number of defined purposes, including "diagnosis, prevention, monitoring, treatment or alleviation of disease" (European Communities 1993, p. 5). As clarified in recital 6 of Directive 2007/47/EC, which amends Directive 93/42/EEC, such a definition includes software:

> Software in its own right when specifically intended by the manufacturer to be used for one or more of the medical purposes set out in the definition of a medical device, is a medical device. (European Union 2007, p. 1)

12.1.2.4 Essential Requirements

Before being allowed to circulate freely in the EU internal market, article 3 of the MDD states, "all devices must meet a series of 'Essential Requirements'" (European Communities 1993, p. 9). These requirements are found in Annex I of the directive. They range from general prescriptions, such as "eliminate or reduce risks as far as possible" (European Communities 1993, p. 25), to more specific, technical, organisational, informational, ergonomic, and requirements. The following list is a non-exhaustive list but purposefully offered to give an idea of the multifaceted safety issues that (may) appear on the medical device developers' list. They include the choice of materials; issues of flammability; design, manufacture, and packaging; risks connected with environmental conditions such as magnetic fields, pressure, temperature or variations in pressure; interference with other devices; obsolescence of materials; loss of accuracy of any measuring or control mechanism; physical resistance, stability and moving parts, vibrations, noise, heat from accessible parts of the device; sufficient levels of accuracy and stability; device's accuracy as stated by the manufacturer; measurement, monitoring, and display scales; and the respect of ergonomic principles taking account of the device's intended use, etc.

Importantly, these requirements are said "essential" because they apply to all medical devices, although the assessment of the conformity may differ, depending on the risk class apps belong to (European Communities 1993, pp. 25–32).

12.1.2.5 Classification

Article 9 of the directive introduces a classification system based on an estimation of the risk posed by a device to the human body and health (European Communities 1993, p. 12). There are four risk classes: Low – I, IIa, IIb, III – and High. A set of criteria, which are listed in Annex IX of Directive 93/42/EEC, determines to which class devices belong. These criteria, for example, "duration of contact with the body" or "degree of invasiveness", enable manufacturers to anticipate the risk class to which their device belongs, and therefore the type of conformity assessment that is required (European Communities 1993, pp. 52–56).

Any mHealth app, which relies on an external energy source in order to function, is considered as "active medical devices". Active medical devices can pertain to different risk classes. For example, devices intended to allow direct diagnosis or monitoring of vital physiological processes pertain to Class IIa; devices intended for monitoring vital physiological parameters, but "where the nature of variations is such that it could result in immediate danger to the patient" (European Communities 1993, p. 55), say, devices measuring variations in cardiac performance, pertain to Class IIb.

In practice, however, it is not always easy to clarify when a given product is a medical device, in the first place. Secondly, it is not easy to determine the class. The expression "borderline technologies" (European Commission 2011, p. 5) has been coined to refer precisely to cases where it is unclear whether a product falls within the definition of a medical device and to which class of risk. The aforementioned "guidelines" provide practical advice to manufacturers, organisations, public authorities, and users to determine when a software falls under the definition of a medical device.

12.1.2.6 Conformity Assessment

As mentioned earlier, essential requirements apply to all medical devices; however, not all devices are "treated" in the same way. As it is stated in article 11 of the MDD, the risk class determines the type of conformity assessment a device must be subjected to (European Communities 1993, pp. 7–8). This means, in clear, a graduated system of control, which corresponds to the level of potential hazard inherent in the type of device concerned. Once again, the following lines are provided to illustrate the detailed assessment a medical app should undergo, if it were considered medical device.

For example, manufacturers of low-risk Class I devices are only obliged to write a statement to declare that the medical device complies with the requirements in the MDD. Manufacturers then need to apply to a notified body to approve and certify the parts of the manufacturing process that include a function (European Communities 1993, p. 8). Manufacturers of high-risk Class III devices must carry out either an annex II audit of the full quality assurance system, including a design dossier examination or an annex III type examination plus one examination and testing

of each product or homogenous batch of products (Annex IV of the MDD), or one audit of the production quality assurance system (Annex V of the MDD) or an audit of final inspection and testing (Annex VI of the MDD) (European Communities 1993, p. 7). Once the conformity assessment is completed, medical devices can be CE marked (see below) and put into free circulation. Conformity assessment can be a long and costly process.

12.1.2.7 The "CE" Marking

The letters "CE" (from the French "Conformité Européene", meaning "European Conformity") is a declaration informing users that the product bearing it complies with the essential requirements of the relevant European legislation. In line with article 17 of Directive 93/42, devices considered to meet the essential requirements referred to in article 3, mentioned above, must bear the CE marking of conformity when they are placed on the market. The CE marking must appear in visible, legible, and indelible form on the device, on the instructions for use, and, where applicable, on the sales packaging. The CE marking must display the identification number of the notified bodies, introduced below, responsible for its quality assurance. It is prohibited to affix marks or inscriptions that mislead third parties or hide the CE marking (European Communities 1993, pp. 20–21).

12.1.2.8 Notified Bodies, Vigilance System, and the European Database on Medical Devices (EUDAMED)

The first placing on the market of a medical device must involve notification to the competent national authority of the place of residence of the manufacturer. A notified body (NB), established in every Member State (Article 16 of the MDD), carries out the conformity assessment mentioned earlier (European Communities 1993, pp. 19–20). Where a notified body finds that pertinent requirements have not been met or are no longer met by the manufacturer or where a certificate should not have been issued, it will suspend or withdraw the certificate or place restrictions. These bodies are under the obligation to inform the Competent National Authority (CNA), such as the "Federal Agency for Medicines and Health Products" in Belgium, of all certificates issued, modified, supplemented, suspended, withdrawn, or refused.

In addition, the MDD envisages a Medical Device Vigilance System. The aim of this system is to reduce the likelihood of reoccurrence of incidents related to the use of a medical device. Adverse incidents are evaluated and information about them disseminated, where appropriate (European Commission 2016a). This serves to prevent repetition of incidents, such as the Poly Implant Prothèse (PIP) breast implant case, reported below, and improve coordination between notified bodies, for instance, via monthly vigilance teleconferences (European Commission 2014b).

The MDD also requires that data about certified "CE" medical devices is stored in a standardised format in a database called the EUDAMED, a central repository

(European Communities 1993, pp. 17–18). EUDAMED contains information about manufacturers and devices, certificates issued or renewed, modified, supplemented, suspended, withdrawn or refused, as well as data obtained in accordance with the vigilance procedure and data on clinical investigations (European Commission 2010). Its purpose is to provide national competent authorities with fast access to relevant information (European Commission 2012b).

12.1.2.9 The Applicability of Medical Device Law to mHealth Apps: The Intended Purpose Rule

Most mHealth apps engage the literal definition of medical device, provided above. Despite this, they are not considered as medical devices. Therefore the essential requirements and the conformity assessment procedures outlined above do not apply to them. The 2016 Commission guidelines' document, discussed below, states: "those apps that are on the *borderline* and could fall under the medical device definition *could be aligned* with the medical devices requirements as far as possible" (European Commission 2016b, p. 7, our emphasis).

The reason why most mHealth apps escape the purview of the MDD is that the manufacturer, or developer, developed them without an intended medical purpose. In clear, only if the intended purpose of the app is medical, the Medical Device Directive applies. "Intended purpose" indicates the use for which the device is intended "according to the data supplied by the manufacturer on the labelling, in the instructions and/or in promotional materials" (European Communities 1993, p. 7). The European Court of Justice has confirmed the centrality of the intended purpose rule in a case concerning a computer program recording brain activity, called "ActiveTwo" by BioSemi VOF (European Court of Justice 2012).

The case originated when a competitor of BioSemi VOF, Brain Products, argued that "ActiveTwo" could not be allowed to circulate freely, as it was not marketed as a medical device. The Court disagreed, explaining that a medical device must satisfy the essential requirements of the directive and bear the CE marking, only if its manufacturer expressly intends to market it for medical purposes. In contrast, a device that de facto performs an activity that squarely falls within the letter of the definition – such as, in the case at hand, recording brain activity – but is not intended to be used for medical purposes by its manufacturer is not a medical device. Accordingly, the safety certification as a medical device cannot be required (European Court of Justice 2012).

The Court decision clarified that, in order to determine whether a software is a medical device or not, the main criterion is the intended purpose. This criterion is more important than the risk that the device per se can pose to human health, which characterise the US approach and upon which we will return in the conclusion. The initial, basic idea behind the MDD evoked earlier, namely, that all computer programs that meet the definition of a medical device must comply with the MDF's requirements, appears, in fact, as "all computer programs intended by its manufacturers to be medical devices must comply with the MDD". The foregoing means

that mHealth apps may not be "as safe". As will be noted below, this situation is unsatisfactory because "people are actually using this stuff and thinking it's real" (Wired, 2014).

12.1.3 Two Gaps of the MDD in Relation to mHealth Apps

12.1.3.1 Reliability of Apps

In 2015, the European Commission organised a series of stakeholders' meetings about the safety risks posed by mHealth apps. The gatherings identified three areas of risk and needs:

1. The need to ensure that mobile health applications function based on sound clinical evidence
2. The need to provide users with reliable and transparent information about the purpose and functionalities of the apps
3. The need for testing the performance of the apps with different devices (European Commission 2016c)

12.1.3.2 Clinical Evidence

Clinical evidence refers to the scientific credibility of an application, which is generated through validation "by […] specialized professionals, health organization and scientific society" (European Commission 2016c, p. 12). Scientific evidence includes information regarding studies and researches that have been used to withstand it, including clinical evidence, information about the authors and of any conflicts of interest (European Commission 2016c, p. 12). An example of an mHealth app lacking clinical evidence is the "Instant Blood Pressure" app, reported by technological magazine Wired (Wired 2014). The app claimed to be working on strong clinical evidence as its manufacturers claimed that the app "use[d] a patent-pending process developed by a team from the Johns Hopkins University—a world leader in health innovation" (Ibid. 2014). In fact, any clinical evidence supported the app, and the John Hopkins University had not participated in its development (Ibid. 2014).

12.1.3.3 Claims on the Purpose and Functions of mHealth Apps

Clarity and transparency about the purposes and functionalities of apps are essential to enable users, doctors, and patients alike to purchase the "right" app. What an app does can be communicated in the logo, in the instructions, in the labelling, or in any form of communication designed to promote directly or indirectly its services (European Commission 2016c, p. 13).

Several cases, such as the one shown below, suggest there is a lack of transparency on the part of developers when they explain the capabilities of their products. The latter is justified on the ground that an app with an advertised pseudo-medical purpose attracts consumers more than normal apps. For this reason, the indication that the app is not intended to serve a medical purpose is not advertised clearly but specified only in the instructions, which consumers seldom read before purchasing an app. For example, the Instant Blood Pressure app claimed it could take a "blood pressure reading in under a minute using only your iPhone—no cuff required" (Wired 2014). It is only by scrolling down in the app store description that one could find a warning stating that this technology was for "recreational use".

Reportedly (Wired 2014), this notice arguably did not discourage users. The reviews left at the bottom of the app store web page clearly indicate that some users downloaded and used the app believing that they were getting accurate blood pressure measurements from it. In 2013 a group of researchers from the University of Pittsburgh Medical Center screened the catalogue of the default app stores of IOS and Android, searching for apps that claimed to be able to detect skin cancer or to assist users in detecting malignant skin lesions (Wolf et al. 2013). In four cases, apps were described in the instructions as intended for educational purposes and not cancer diagnosis. Despite the obvious medical relevance, the instructions merely warned users not to use them to replace standard medical care (Wolf et al. 2013). As mentioned earlier, "people are using this stuff and thinking it's real" (Wired 2014).

12.1.3.4 Test and Validation of Performance

The performance of a device relates to the accuracy of technology features and components, such as buttons, menus, resistance over time, after prolonged use, etc. (European Commission 2016b, p. 43).

There are general and specific problems related to the testing and validation of apps. A general problem is that apps, like any software, are "impossible to guarantee [being] error-free" (Forsström 1997, p. 143). In this regard, the best way to minimise errors is to conduct tests with users. However, in the low-cost business model of the apps industry, cost-constrained software development validation means that software often undergoes "minimal testing" (Lurie 2003). This is the case, for example, of the "Instant Blood Pressure" app, presented above. Put to the test after being released on the market, the app first measured a heart rate of 55 beats per minute. Reactivated after two misfires, the app measured a heartbeat of 74 per minute (Wired 2014).

The specific problem relates to the fact that mHealth apps, unlike conventional medical software, are designed to work with a potentially enormous range of generic devices. The MDD requires that the testing of a medical device be performed with all the accessories with which it is to be used (European Communities 1993, p. 6). In other words, the essential requirements must be met by the app, working in combination with the accessory (the mobile device) (European Commission 1994). This

includes software, called "stand-alone software", which is not incorporated into a device at the time of its placing on the market (European Commission 2016d). To come into line with the directive, apps should be tested on every mobile device that can run it. In addition, given the versatility of operating systems such as Android, such apps may well be capable of being run on phones that did not even exist when the app in question was created. This apparent impossibility to test the medical device with all available accessories poses unknown safety issues (Quinn 2013).

12.1.3.5 Traceability of mHealth Apps

The other safety issue highlighted in EU-sponsored stakeholders' meetings concerns the possibility of retrieving defective apps from users. In general, the recall of products is exercised when a device is defective, poses a risk to health, or both, for example, a critical bug in a software. Launching a recall procedure can be a legal obligation. It is found in community legislation on medicinal products (European Union 2001, p. 72; European Union 2003, p. 25). Under these directives, manufacturers must implement a system for recording and reviewing complaints, together with an effective system for recalling promptly and at any time (investigational) medicinal products, which have already entered the distribution network.

Recall is also foreseen under the MDD. In Annex IV, the MDD obliges manufacturers to implement "any necessary corrective action", including the recall of devices (European Communities 1993, pp. 40–41). Annex VII of the same piece of legislation requires manufacturers to notify the competent authorities of "any technical or medical reason […] leading to systematic recall of devices of the same type by the manufacturer" (European Communities 1993, pp. 48–49).

A case in which medical devices had to be recalled occurred in 2009, after some French surgeons began reporting an abnormally high rupture rate of breast implants produced by a company called Poly Implant Prothèse (PIP). Some months later the French medical safety agency (AFSSAPS) issued a recall of PIP implants when it found out that company was substituting unapproved silicone in place of approved medical-grade silicone (Keogh 2012). The French government later recommended the removal of PIP implants and announced that the 30,000 French women who received PIP implants were entitled to have them removed at no cost (Chrisafis 2011).

The PIP case concerns a traditional, material, medical device. In the specific context of mobile health apps, however, it may not be easy to implement a recall procedure. The reason for this is that it is difficult to trace the different channels through which an app without a CE mark can be distributed. An app that is not a medical device can be downloaded from app stores or directly from the Internet. A manufacturer may contact the app stores to retrace those who downloaded the app and contact them (Article 29 Data Protection Working Party 2013, pp. 20–21). But in case a defective app has not been downloaded from official channels, for instance, from a privately owned website, tracing the user concerned is more difficult. This

holds true in particular for apps that, once they are downloaded, work autonomously, i.e. without the need to stay connected to the Internet. In this case, it is only the owner of the mobile device that can uninstall the defective app. To do so, he or she must be told, as the example below shows.

In April 2011, the multinational pharmaceutical company Pfizer Inc. released a "Rheumatology Calculator" app. This app was not a CE-marked medical device and, once downloaded, could work offline. The app was a calculator, as its functionality was to help physicians to "measure the disease activity of patients with various inflammatory diseases, in particular that of patients with rheumatoid arthritis" (Pfizer 2011). The Pfizer app, more specifically, used an algorithm to measure specific markers of disease activities of patients based on data provided by their doctors.

In October 2011, the app disappeared from the app stores, and Pfizer informed the British and the Swiss competent authorities that it had found a bug in the software. Pfizer also sent a letter to many doctors based in the UK informing them that:

> "a bug in the app […] gives wrong results", and that "if you have downloaded the "Pfizer Rheumatology Calculator" application to your mobile device, the application should not be used any longer and should be deleted from the device". (Ibid, 2011)

It is not clear how many doctors Pfizer tried to contact. It is not equally clear why the company decided to send the letter only to British doctors (Ibid, 2011). More worryingly, it is unknown whether there are doctors out there who, not having being informed, are still using the calculator in their daily work.

12.1.3.6 Regulatory Initiatives to Address the Safety Needs of mHealth Apps

European authorities have been hesitant to impose the requirements of the MDD on apps (Quinn 2013). The reason for this is that stricter enforcement of the MDD may stifle an area of ongoing innovation and potential growth (European Commission 2012a). Given the costs involved with MDD compliance, a more rigorous application of the MDD would likely mean an increase in the cost of such applications beyond a level which may be feasible for a low-cost business model.

However, recently, the EU has grown aware that the safety concern is a barrier to the very uptake of mHealth. In 2016, the European Commission launched a guidelines document to ensure "a consistently high level of health and safety protection for EU citizens using mHealth apps" in which the reliability and transparency needs discussed earlier are cautiously addressed (European Commission 2016c). In response to the specific problem of traceability, no specific initiative has been adopted. However, the newly proposed Medical Device Regulation (European Commission 2012a) introduces a unique device identifier (UDI) system that may be used to mitigate that problem (see below page 12).

12.1.3.7 The EU Guidelines on the Assessment of the Reliability of Mobile Health Applications

In 2016, the European Commission adopted the first draft of the "EU guidelines on assessment of the reliability of mobile health applications". The EU guidelines, which are not legally binding, deal with the grey zone of "borderline" mHealth apps (European Commission 2016c, p. 4). Drafted by a private consultancy contracted by the Commission, the "EU guidelines" contain an assessment procedure that takes the form of a series of precise questions.

The EU guidelines document is structured in three sections, one for each of the three stages of the assessment process. Each step consists of a series of questions addressed to app developers, citizens, health professionals, and health providers alike.

The first step is concerned with the identification of the app, to discover if it exists, if it is appropriate for the evaluation, whether it is downloadable (Ibid., pp. 8–9), its name, the supplier and the developer (in the case that they are not the same), and the intended use declared by the manufacturer. In the case that the app is "CE" marked, there is no need to carry out an assessment (Ibid., p. 8). If not, mHealth apps must undergo a simple testing, which consists of installing and uninstalling the app on available platforms and verifying whether the app is easy to understand, easy to navigate, and if it works as stated (Ibid, p. 9).

In the second step, "risk assessment", the information gathered about the app is used to rank the clinical and technological risk. Depending on its specificities, each app will be ranked differently; this ranking, in turn, determines the level of "scrutiny" the app should be submitted to (see below third phase "scrutiny"). This stage, in other words, helps stakeholders to clarify the appropriate level of conformity assessment that the app they have in mind "may" undergo.

In the third phase, called "scrutiny", a series of questions about the technological and the medical aspects of the app are asked (Ibid., pp. 11–15). As far as the problem of clinical evidence is concerned, the guidelines dedicate seven questions to assess the credibility of the app. These questions include: "Does the app provide references to the scientific evidence used to ensure content quality?" "Is there appropriate information provided about the authors of the app content to generate credibility and provide quality assurance?" "Does it indicate how often the app's content is reviewed/updated?" "Does it indicate the last review date?" "Does it notify changes/modifications made at the last update?" (Ibid., p. 12).

As far as the transparency about the claims of the app, the EU guidelines recommend, as first step, to give a face to the app, that is, who are those developing and introducing the app in the market. Moreover, the guidelines urge more clarity about the intended purpose of the app. Users should be able to understand right away what the app can do and what it cannot do. The detailed questions asked by the guidelines complement the transparency obligations that already exist under community law. The eCommerce Directive 2000/31/EC and Directive 2011/83/EC, the Directive on Consumer Rights, impose on manufacturers a series of obligations intended to ensure that consumers who purchase an app "at the distance" are informed in

transparent and clear fashion (European Union 2000; European Union 2011). Furthermore, Directive 2005/29/EC on Unfair Commercial Practices sanctions unfair commercial practices. On the account of the directive, a commercial practice is unfair if it does not comply with the principle of professional diligence, if it is likely to distort the economic behaviour of the average consumer, and if it is misleading or aggressive (European Union 2005, p. 28).

As per the problem of testing the performance of the app with the different devices, the guidelines propose to involve and, more specifically, to encourage users to test the apps "in every platform" (European Commission 2016b, p. 11).

12.1.3.8 The Unique Device Identifier

In 2013 the Commission acknowledged in a recommendation that the "traceability of medical devices throughout the whole supply chain contributes to patient safety by facilitating vigilance, market surveillance and transparency in this sector" (European Commission 2013, p. 1). In that same text, the Commission advocated for a unique device identification system of medical devices in the EU (Ibid., p. 1). The proposed reform of the MDF, the draft Medical Device Regulation (MDR), introduces a unique device identification (UDI) mechanism.

The Unique Device Identification (UDI) is a unique numeric or alphanumeric code that pertains to any medical device. Such a unique numeric or alphanumeric is composed of two parts, a device identifier and a production identifier. By combining these identifiers, the UDI is expected to improve the traceability of devices and allow for easier recall of devices, as well as for combatting counterfeiting. The UDI will not replace but add to the existing labelling requirements of the Medical Device Directive (European Commission 2016a).

In the intention of the Commission, Eudamed is expected to take a more important role under the new regulation, improving the capacity of medical authorities to trace devices through the supply chain and to facilitate the prompt and efficient recall of "bad", unsafe, devices from the market and from consumers' hands.

12.1.3.9 A Brief Look into the US Legislative Framework for "Borderline" mHealth Apps

The US approach to regulating mHealth apps display similarities and some differences from the European Union's. This section presents the US legal framework on medical devices, focusing on what interests this chapter, the regulation of "borderline" mHealth apps.

The centrepiece legislation for the safety for medical devices in the USA is the Federal Food, Drug, and Cosmetic Act (FD&C Act) of 1938 (United States Congress 1938). The Medical Device Amendment of 1976 introduced in the FD&C criteria and norms for the classification and regulation of medical devices. The same amendment entrusted to a federal authority, the Food and Drugs Administration (FDA), the

role of ensuring that a "reasonable assurance of safety and effectiveness" is provided before medical devices are marketed and, importantly, the power to investigate and discontinue the commercialisation of apps that are deemed to pose a serious risk to the health and safety of users/patients (United States Congress 1976).

In the last few years, like in the European Union, the FDA has issued guidelines to clarify the application of medical device law to mHealth apps. As in Europe, these "guidance documents" do not establish legally enforceable responsibilities but contain non-binding recommendations. The most relevant instruments, for our purposes, include:

(a) The *Mobile Medical Applications Guidance* of 2013, subsequently amended in 2015, which seeks to provide clarity and predictability for manufacturers of mobile medical apps (US Food and Drugs Administration 2013a; US Food and Drugs Administration 2015a)
(b) The *Medical Device Data Systems*, *Medical Image Storage Devices*, *and Medical Image Communications Devices* of 2015, which covers devices used to collect and store data from other medical devices (US Food and Drugs Administration 2015b)
(c) The *Medical Device Accessories*: *Defining Accessories and Classification Pathway for New Accessory Types Guidance* of 2016, which deals with accessories to medical devices (US Food and Drugs Administration 2016a)
(d) The *General Wellness*: *Policy for Low-Risk Devices Draft Guidance of 2016*, which deals with low-risk products that promote healthy lifestyle or general wellness products, such as fitness trackers, calorie trackers, or lifestyle trackers (US Food and Drugs Administration 2016b)

The definition of medical device introduced in the FD&C Act is similar to the one adopted in the EU. Section 201(h) of FD&C Act considers a medical device "an instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or other similar or related article, including a component part, or accessory" (United States Congress 1938, p. 5). In contrast to the European MDD, in order to determine whether a device is a medical one, the US legislator appeals to the "intended use" criterion. A device is medical if it is:

> Intended for use in the diagnosis of disease or other conditions, or […]; or intended to affect the structure or any function of the body of man or other animals […]. (United States Congress 1938, p. 5)

The intended use may be shown by oral or written statements (by manufacturers or their representatives) or by labelling claims or by advertising materials (United States Congress 1938, pp. 322–329). As discussed earlier, in the EU MDD, the criterion is the "purpose", "intended by the manufacturer" (European Communities 1993, p. 5); in the USA such a specification does not exist. This means that while in Europe a company can avoid compliance with the medical device legislation by disavowing an app's medical purpose, in the USA "when it is clear that the app serves as a medical device, such disavowals are ineffective" (McFarlane 2014, p. 3).

The case of 23andME, discussed below, illustrates the practical implications of this provision.

The similarities and differences between the USA and the EU do not stop here. Similar to the European MDD, the US FD&C Act organises medical devices into classes (United States Congress 1938, pp. 191–200). While in Europe there are four classes, US legislation provides for three classes: "low-risk" Class I devices, which are subject only to general controls, such as registering their name and products with the FDA; medium-risk Class II devices, which are expected to meet performance standards and undergo specific controls; and high-risk Class III devices, which must be subjected to a review process, including clinical trials, before they are allowed to be marketed (Kramer et al. 2012). Notwithstanding the difference in the number of classes, the logic behind the classification remains the same, based on prior evaluation of the risks that type of device poses to the health and safety of the patient.

Both the EU and US regulators face the similar challenge of ensuring that borderline apps that are sold in the market are safe (Sorenson and Drummond 2016, pp. 145–150). As discussed earlier, the EU legislator asks manufacturers of borderline apps to abide by "as close as possible" to the requirements of the MDD. In contrast, the US FDA refrains from the attempt of bringing borderline apps under the umbrella of the FD&C Act (*US Food and Drugs Administration* 2015c). The FDA reserves to itself the power to intervene if a borderline app is procuring a high risk. In its website, the FDA offers a list of examples of mobile apps that "may be regulated" (*US Food and Drugs Administration* 2016c): apps that transform a mobile platform into a regulated medical device using sensors or by including functionalities similar to those used in other regulated devices, apps that are used for patient monitoring or that analyse data from a connected device, etc. (*US Food and Drugs Administration* 2016c).

Both the EU and the US legislator have put in place vigilance systems. Also in the USA, manufactures of marketed devices are, for instance, under the obligation to report adverse events and to continue monitoring the device's safety and effectiveness (Kramer et al. 2012). The FDA also supports a number of the so-called surveillance data networks, the Medical Device Epidemiology Network Initiative (MDEpiNET) and the Medical Device Surveillance Network (MedSun). These networks conduct systematic collection, collation, and analysis of data to identify safety problems and advance epidemiological research (Fiedler 2016, p. 56). Since 2013, a Unique Device Identification (UDI) system and a central database of medical devices (GUDID) have been in place (*US Food and Drugs Administration* 2013c). The system and the database share similarities with the tasks performed by European notified bodies, for what concerns the post market surveillance, and by EUDAMED, the central database of medical devices, for what concerns surveillance data.

The case of the company "23andMe" offers an example of what we have briefly discussed so far concerning the regulation of borderline apps in the USA. 23andMe is a private company that provides consumers with information about their genetic

heritage, using a sample of their saliva, and against the payment of a price ($99) (23andme 2013).

In 2011, when it started operating, the purpose of 23andMe was to offer a genetic testing service, which provided clients with information about their ancestors. Shortly thereafter, the company launched another service: clients could now obtain genetic information revealing their predisposition to develop certain pathologies or their responsiveness to certain drugs (Brandon 2013). The new service proved extremely successful and profitable. The popularity of the service, however, attracted the attention of the federal authority, the FDA. Few months after, the FDA ordered 23andMe to discontinue the marketing of its genetic diseases predictive services, while it could keep the genealogical services in place. For the FDA, the genetic testing kit posed a serious risk to individuals because (1) it did not provide sufficient information about the reliability of the "predisposition" diagnoses, (2) it did not give advice to consumers about how to navigate the information extracted from the kit, and (3) it provided misleading information, suggesting to users that the test could replace traditional medical diagnosis (*US Food and Drugs Administration* 2013b). Today, 23andMe has obtained the certification of the FDA also for its predictive genetic testing services. However, a warning appears in its website making clear that the tests:

> Are not intended to diagnose a disease, or tell you anything about your risk for developing a disease in the future" and they are "not intended to tell you anything about the health of your fetus, or your newborn child's risk of developing a particular disease later in life. (23andme 2016)

In conclusion, there are not substantial differences between the EU and US approach to borderline medical apps, which are both lenient in imposing the application of the respective medical device frameworks. Under both jurisdictions, regulators have been hesitant to take action that they fear may stifle an area of ongoing innovation. The difference between the EU and the USA is perhaps mostly related to the regulation technique. The European framework tends to be overarching and participative. It seeks to cover all apps, including borderline apps, and promotes stakeholders' self-regulation through self-assessment of their products. In the USA, the legislator is less interested in extending the medical devices rules to borderline apps or in involving stakeholders. Developers are warned that a US federal authority retains the power to intervene at any moment should a borderline app pose serious risks to health.

12.2 Conclusion

This chapter has raised the question of the use of commercially available mHealth apps for medical purposes. To answer the main research question, "are mHealth apps safe?", it has mobilised the EU's Medical Device Framework. This detailed legal system of administrative rules, checks and testing, documentary procedures,

and requirements, amended over the years, does not clearly apply to most mHealth apps. "Borderline" apps that are not intended by their manufacturers to be used for medical purposes do not have to comply with it. This also holds true if they technically meet the definition of a medical device and/or they perform acts on subjects that doctors would consider pertaining to the medical field. The non-applicability of the MDF to borderline mHealth apps implies a general "market clearance" given to de facto medical-connected devices that potentially affect individuals' health, without medical justification.

This situation creates safety problems that, as discussed in this contribution, concern primarily the "reliability" and the "traceability" of "bad" apps. Clinical evidence, claims on the purpose and functions of mHealth apps, procedures for testing and validating of performance, and the traceability of mHealth apps are the issues of major concern. The recent EU guidelines offer general and specific questions to address them by guiding "stakeholders" in the self-assessment of the credibility, the solidity, etc. of the apps and their functionalities. The guidelines closely reflect the MDD. Indeed, after reading the questions, one comes under the impression of being spoon-fed medical device law for non-experts. This is done in the attempt to bring the mHealth apps market "as close as possible" to the medical device framework, as recommended by the EU.

This apparently positive effort can be put into question. In particular, one may raise doubts about the rationale behind the decision of addressing the guidelines not only to manufacturers or developers but to all stakeholders. The point should be emphasised that stakeholders in mHealth carry different points of view (Bijker 2010): they have specific interests and concerns and also constraints that limit what they can actually do. Manufactures will read the guidelines because they need to know whether they have to comply, and with which parts, of the complex medical device framework. Other stakeholders, such as doctors and patients, may very well read the guidelines, but they cannot really make a difference. Their concern is to decide whether or not to use an app, which has already been produced. A more useful guidance is, for example, the Medical App Checker of the Royal Dutch Medical Association (KNMG 2016).

What is worrisome is the proclivity of the EU to include "all stakeholders". This choice is seemingly premised on the assumption if the rules are well explained, "all stakeholders" will be able to self-assess the risks of apps that are about to develop, recommend, purchase, use, etc. In our view, this "pedagogic" approach may create unnecessary confusion; it may, most importantly, dilute the responsibilities of those primarily concerned with the development of safe apps, app developers, or manufacturers.

In an earlier publication (Mantovani et al. 2013, p. 66), one of the authors suggested that we were approaching a fork in the road. In that article, one route led towards a future where mHealth apps are regulated according to the same principles as conventional medical devices; the other route was to continue with the current situation whereby mHealth apps are allowed to avoid the need of complying with medical device regulation. Looking at the most recent legislative initiatives, it seems that mHealth is threading the second route. In this connection, and to mitigate the

risk of diluting the responsibilities of the developers, just evoked, the EU could benefit from two lessons learnt from the regulation of borderline mHealth apps in the USA.

First, while the EU's technique to regulate borderline mHealth apps appears overarching and participative/pedagogical, in the USA the "activity of attempting to control, order or influence" (Black 2002, p. 1, mentioned in the Introduction) the development of mHealth apps could be said "sector specific" and "adversary". It is sector specific because the regulatory frameworks, including the guidelines, address developers of mHealth apps only; it is adversary because a federal authority, the FDA, retains a discretionary power of intervention. Although it exercises its power only in a restricted number of cases, this system boils down to a warning for manufactures that if the use of a device or app poses serious risks to health, the FDA will intervene, forcing the application under the medical device framework, regardless of the intended use that the developer attributed to it (as in the 23andMe case).

In our view, the EU regulation of mHealth apps may consider an expansion of the domain of activity of public authorities in the mHealth safety domain. The EU has a long tradition of creating networks of supervisory bodies, for instance, the data protection authorities (DPAs) under Directive 95/46/EU. To guarantee a high level of health safety in a world of connected devices, the existing independent authorities, at national and/or European level, could be able to receive complaints or notifications by stakeholders concerned with the safety of apps. Legislative change may be required to make rights enforceable, and it may be necessary to adopt an approach similar to that found in the distant selling and consumer directives, i.e. whereby consumers are able to ask questions and obtain genuine information from app developers.

Second, the US authorities accept the situation where one does not know if certain lifestyle and well-being apps pose a risk to citizens' health and to what extent, until they are reported, investigated, and/or accidents occur. It is hard to deny that this statement candidly reflects the reality of uptake of mHealth today, not only in the USA but also in Europe. What is noteworthy is that the formal recognition of this situation in the USA means that if an app poses a risk to health, it will not be enough for an app developer to disavow the medical or pseudo-medical purpose of use. Regardless of the purpose intended by its manufacturer, if an app poses a risk to health, it is stopped and must undergo the medical device standard procedure before being marketed again.

In our view, the EU regulation of mHealth apps could also consider risk assessment, in addition to the "intended purpose" rule, to distinguish between medical and non-medical mHealth apps. Embracing risk assessment would mean opening the doors to independent scientific advice on all aspects relating to safety, communication, and dialogue with consumers, as well as networking with national agencies and scientific bodies. This process may be costly and difficult to realise across different Member States. It may be worth trying. Unchecked medical technology developments have the potential not only to harm the health of individual; they can also engender fears and mistrust in the public, to the detriment of any medical technological innovation.

Acknowledgements The authors acknowledge the support of the IRIS project – Interoperable platform for Remote monitoring and Integrated e-Solutions (Grant agreement Nr. BRGEOZ234), funded by INNOVIRIS, the Brussels Institute for Research & Innovation.

References

Article 29 Data Protection Working Party (2013) Opinion 02/2013 on apps on smart devices. http://ec.europa.eu/justice/data-protection/article-29/documentation/opinion-recommendation/files/2013/wp202_en.pdf. Accessed 21 Dec 2016

Bijker WE (2010) How is technology made?—that is the question! Camb J Econ 34:63–76

Black J (2002) Critical reflections on regulation 27 Australian Journal of Legal Philosophy 1

Brandon R (2013) Body blow: how 23andMe brought down the FDA's wrath. http://www.theverge.com/2013/11/25/5144928/how-23andme-brought-down-fda-wrath-personal-genetics-wojcicki. Accessed 21 Dec 2016

Callens S (2010) The EU legal framework on E-health. In: Mossailos E, Permanand G, Baeten R, Hervey T (eds) Health systems governance in Europe. Cambridge University Press, Cambridge

Chrisafis A (2011) French government "to order women to remove defective breast implants". https://www.theguardian.com/world/2011/dec/20/french-remove-breast-implants-silicone. Accessed 21 Dec 2016

Cortez N (2014) The mobile health revolution? http://lawreview.law.ucdavis.edu/issues/47/4/articles/47-4_cortez.pdf. Accessed 2 Jan 2017

Danzis SD, Pruitt C (2013) Rethinking the FDA's regulation of mobile medical apps. https://www.cov.com/~/media/files/corporate/publications/2013/02/rethinking_the_fdas_regulation_of_mobile_medical_apps.pdf. Accessed 1 Jan 2017

Deloitte (2012) mHealth in an mWorld. https://www2.deloitte.com/content/dam/Deloitte/us/Documents/life-sciences-health-care/us-lhsc-mhealth-in-an-mworld-103014.pdf. Accessed 25 Nov 2016

DigitalTrends (2016) Maintain your health and mind with these 15 medical apps. http://www.digitaltrends.com/mobile/best-medical-apps/. Accessed 5 Dec 2016

European Commission (1994) MEDDEV 2.1/2 guidelines rrelating to the application of: the council directive 90/385/EEC on active medical devices and the council directive 93/42 on medical devices. http://ec.europa.eu/consumers/sectors/medical-devices/files/meddev/2_1-2___04-1994_en.pdf. Accessed 21 Dec 2016

European Commission (2010) 2010/227/: Commission Decision of 19 April 2010 on the European Databank on Medical Devices (Eudamed) (notified under document C (2010) 2363) (Text with EEA relevance) http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010D0227&from=en. Accessed 11 Dec 2016

European Commission (2011) Manual on borderline and classification in the community regulatory framework for medical devices. http://ec.europa.eu/consumers/sectors/medical-devices/files/wg_minutes_member_lists/version1_9_borderline_manual_en.pdf. Accessed 21 Dec 2016

European Commission (2012a) Proposal for a regulation of the European parliament and of the council on medical devices, and amending directive 2001/83/EC, regulation (EC) No. 178/2002 and regulation (EC) No. 1223/2009. http://ec.europa.eu/health/medical-devices/files/revision_docs/proposal_2012_542_en.pdf. Accessed 15 Oct 2016

European Commission (2012b) Evaluation of the "European databank on medical devices". http://ec.europa.eu/DocsRoom/documents/12981/attachments/1/translations/en/renditions/native. Accessed 21 Dec 2016

European Commission (2013) Commission recommendation on a common framework for a unique device identification system of medical devices in the union text with EEA relevance. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013H0172&from=EN. Accessed 17 Dec 2016

European Commission (2014a) Green paper on mobile health. http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=5147. Accessed 21 Dec 2016

European Commission (2014b) EU consultation on mHealth. https://ec.europa.eu/digital-single-market/en/public-consultation-green-paper-mobile-health. Accessed 5 Dec 2016

European Commission (2016a) Market surveillance and vigilance. Available at: https://ec.europa.eu/growth/sectors/medical-devices/market-surveillance_en. Accessed 1 Nov 2016

European Commission (2016b) MEDDEV 2.1/6 guidelines on the qualification and classification of stand alone software used in healthcare within the regulatory framework of medical devices. http://www.twobirds.com/~/media/pdfs/news/articles/2016/firstdraftguidelinesandannexes.pdf?la=en. Accessed 13 Dec 2016

European Commission (2016c) EU guidelines on assessment of the reliability of mobile health applications. http://ec.europa.eu/newsroom/dae/document.cfm?action=display&doc_id=16090. Accessed 13 Dec 2016

European Commission (2016d) Code of conduct on privacy in mHealth. http://ec.europa.eu/newsroom/dae/document.cfm?action=display&doc_id=16125. Accessed 13 Dec 2016

European Communities (1990) Directive 90/385 on the approximation of the laws of the member states relating to active implantable medical devices. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31990L0385&from=EN. Accessed 10 Oct 2016

European Communities (1993) Directive 93/42 concerning medical devices. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1993L0042:20071011:EN:PDF. Accessed 21 Dec 2016

European Communities (1998) Directive 98/79/EC of the European parliament and of the council of 27 October 1998 on in vitro diagnostic medical devices. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31998L0079. Accessed 13 Nov 2016

European Court of Justice (2012) C129/11 Brain Products GmbH v. BioSemi VOF. http://curia.europa.eu/juris/document/document.jsf?docid=130247&doclang=en. Accessed 12 Oct 2016

European Union (2000) Directive 2000/31/EC of the European parliament and of the council of 8 June 2000 on certain legal aspects of information society services, in particular electronic commerce, in the internal market ('Directive on electronic commerce'). http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0031:EN:HTML. Accessed 16 Nov 2016

European Union (2001) Directive 2001/83/EC of the European parliament and of the council of 6 November 2001 on the community code relating to medicinal products for human use. http://ec.europa.eu/health//sites/health/files/files/eudralex/vol-1/dir_2001_83_consol_2012/dir_2001_83_cons_2012_en.pdf. Accessed 16 Nov 2016

European Union (2003) Commission directive 2003/94/ECof 8 October 2003 laying down the principles and guidelines of good manufacturing practice in respect of medicinal products for human use and investigational medicinal products for human use. http://ec.europa.eu/health//sites/health/files/files/eudralex/vol-1/dir_2003_94/dir_2003_94_en.pdf. Accessed 16 Nov 2016

European Union (2005) Directive 2005/29/EC of the European parliament and of the Council of 11 May 2005concerning unfair business-to-consumer commercial practices in the internal market and amending council directive 84/450/EEC, directives 97/7/EC, 98/27/EC and 2002/65/EC of the European parliament and of the council and regulation (EC) No 2006/2004 of the European parliament and of the council('Unfair Commercial Practices Directive'). http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32005L0029&from=en. Accessed 16 Nov 2016

European Union (2007) Directive 2007/47/EC of the European parliament and of the council of 5 September 2007 amending council directive 90/385/EEC on the approximation of the laws of the member states relating to active implantable medical devices, council directive 93/42/EEC concerning medical devices and Directive 98/8/EC concerning the placing of biocidal products on the market. http://ec.europa.eu/consumers/sectors/medical-devices/files/revision_docs/2007-47-en_en.pdf. Accessed 17 Nov 2016

European Union (2011) Directive 2011/83/EU of the European parliament and of the council of 25 October 2011on consumer rights, amending council directive 93/13/EEC and Directive 1999/44/EC of the European parliament and of the council and repealing council directive 85/577/EEC and directive 97/7/EC of the European parliament and of the council. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011L0083&rid=1. Accessed 15 Nov 2016

European Union (2012) Treaty on the functioning of the European union. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:12012E/TXT&from=EN. Accessed 3 Aug 2016

Fiedler BA (2016) Managing medical devices within a regulatory framework. Elsevier, Cambridge, MA

Forsström J (1997) Why certification of medical software would be useful? Int J Med Inform 47(3):143–151

Google Play (2013) COPD – NHS decision aid. https://play.google.com/store/apps/details?id=uk.co.activata.TotallyHealth.condition119. Accessed 5 Dec 2016

Google Play (2016) Telemed. https://play.google.com/store/apps/details?id=com.telemed.ae&hl=es. Accessed 5 Dec 2016

Hanlon B, Thiel S (2016) The mobile health application revolution: tapping its potential. http://www.covance.com/content/dam/covance/assetLibrary/whitepapers/Mobile-Health-Applications-WPCVD002-0816.pdf. Accessed 3 Jan 2017

Hildebrandt M (2015) Smart technologies and the end(s) of law: novel entanglements of law and technology. Edward Elgar Publishing, Cheltenham

Huckvale P, Tilney B, Car (2015) Unaddressed privacy risks in accredited health and wellness apps: a cross-sectional systematic assessment. BMC Med 13:214

IHS report (2013) The world market for sports & fitness monitors—2013 Edition

International Telecommunications Union (2014) Filling the gap: legal and regulatory challenges of mobile health (mHealth) in Europe. https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/ITU%20mHealth%20Regulatory%20gaps%20Discussion%20Paper%20June2014.pdf. Accessed 21 Dec 2016

Itunes (2015) Self-help for anxiety management. https://itunes.apple.com/us/app/self-help-for-anxiety-management/id666767947?mt=8. Accessed 20 Dec 2016

Keogh B (2012) Poly implant Protheses(PIP) breast implants: interim report of the expert group. http://www.nhs.uk/news/2012/01January/Documents/pip-report.pdf. Accessed 22 Dec 2016

KNMG (2016) Medical app checker: a guide to assessing mobile medical apps http://www.knmg.nl/Over-KNMG/About-KNMG/News-English/152830/Medical-App-Checker-a-Guide-to-assessing-Mobile-Medical-Apps.htm

Kramer DB, Xu S, Kesselheim AS (2012) Regulation of medical devices in the United States and European Union. N Engl J M 366(9):848–855

Lurie J (2003) Error-free software is in reach, but is anyone reaching?. http://www.devx.com/enterprise/Article/16687. Accessed 1 Aug 2016

Mantovani E, Guihen Barry B, Quinn P, Habbig A-K, De Hert P (2013) eHealth to mHealth. A journey precariously dependent upon apps? Eur J ePractice 21:48–66

McFarlane B (2014) FDA regulation ofmobile medical apps. https://www.namsa.com/wp-content/uploads/2015/10/WP-FDA-Regulation-of-Mobile-Medical-Apps-7-7-2014.pdf. Accessed 21 Dec 2016

Medical Device and Diagnosis Industry (2015) Consumer mHealth app or regulated medical device? http://www.mddionline.com/blog/devicetalk/consumer-mhealth-app-or-regulated-medical-device-03-04-15. Accessed on 14 Nov 2016

Pew Research (2013) Tracking for health. Available at http://www.pewinternet.org/2013/01/28/tracking-for-health-2/. Accessed 2 Sept 2017

Pfizer UK (2011) Dear doctor letter: “Pfizer rheumatology calculator” iPhone/android application — important information. Available at: http://www.pharma-mkting.com/images/Pfizer_Rheum_BugLetter.pdf. Accessed 20 July 2016

Prainsack B (2014) The powers of participatory medicine. PLoS Biol 12(4):e1001837

Quinn P (2013) Medical apps and accountability – where can the patient/consumer find protection? European Journal of Health Law. Fourth Conference on European Health Law, Book of Abstracts

Rübsamen K, Sakellariou S (2015) Mobile health apps: are they a regulated medical device?. http://www.whitecase.com/publications/article/mobile-health-apps-are-they-regulated-medical-device. Accessed 1 Jan 2017

Sorenson C, Drummond M (2016) Improving medical device regulation: the United States and Europe in perspective. Milbank Q 92(1):145–150

United States Congress (1938) Federal Food, Drug, and Cosmetic Act. https://www.epw.senate.gov/FDA_001.pdf. Accessed 8 Aug 2016

United States Congress (1976) Medical device amendment. https://www.congress.gov/bill/94th-congress/house-bill/11124. Accessed 8 Aug 2016

US Food and Drugs Administration (2013a) Mobile medical Applications. http://www.gpo.gov/fdsys/pkg/FR-2013-09-25/pdf/2013-23293.pdf. Accessed 6 Dec 2016

US Food and Drugs Administration (2013b) 23andMe, Inc. 11/22/13. Available at: http://www.fda.gov/ICECI/EnforcementActions/WarningLetters/2013/ucm376296.htm. Accessed 6 Dec 2016

US Food and Drugs Administration (2013c) Unique device identification system-final rule. http://www.fda.gov/downloads/aboutfd/ucm368961.pdf. Accessed 6 Dec 2016

US Food and Drugs Administration (2015a) Mobile medical applications. Available at: http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM263366.pdf. Accessed 6 Dec 2016

US Food and Drugs Administration (2015b) Medical device data systems, medical image storage devices, and medical image communications devices. http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM401996.pdf. Accessed 6 Dec 2016

US Food and Drugs Administration (2015c) Draft guidance for industry and food and drug administration staff. http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM429672.pdf. Accessed 6 Dec 2016.

US Food and Drugs Administration (2016a) Examples of mobile apps for which the fda will exercise enforcement discretion. Available at: http://www.fda.gov/MedicalDevices/DigitalHealth/MobileMedicalApplications/ucm368744.htm. Accessed 9 Dec 2016

US Food and Drugs Administration (2016b) Medical device accessories–describing accessories and classification pathway for new accessory types. Available at: http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM429672.pdf. Accessed 6 Dec 2016

US Food and Drugs Administration (2016c) General wellness: policy for low risk devices. Available at: http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM429674.pdf?source=govdelivery&utm_medium=email&utm_source=govdelivery. Accessed 6 Dec 2016

Wired (2014) These medical apps have doctors and the FDA worried. http://www.wired.com/2014/07/medical_apps/. Accessed 8 Aug 2016

Wolf J, Moreau J, Akilov O et al (2013) Diagnostic inaccuracy of Smartphone applications for melanoma detection. JAMA Dermatol 149(4):422–426

23andMe (2013) A look At 23andMe’s DNA revolution. https://blog.23andme.com/news/a-look-at-23andmes-99-dna-revolution/. Accessed 8 Aug 2016

23andMe (2016) Order. https://store.23andme.com/en-int/cart/. Accessed 8 Aug 2016

Eugenio Mantovani is research fellow at the interdisciplinary research on Law, Science, Technology and Society (LSTS) at the Vrije Universiteit Brussel (VUB). Eugenio's research interests include the law on data protection and privacy, with particular focus on the area of health care delivery. He is interested in the evolving use of technologies for ageing societies and has published a number of articles on these issues. His doctoral thesis delves on the relationships between ageing and technology, which he broaches from the point of view of the law. Eugenio has been active in a number of European research projects with a focus on these themes.

Pedro Cristobal Bocos is a researcher at the VUB, where he focuses on the relation between new technologies and fundamental rights from a European Union regulatory perspective. He is currently working at the Interoperable platform for Remote monitoring and Integrated e-Solutions (IRIS) project for the development of an open-source and secure ICT platform for interoperable collection and communication of wireless 3G/4G audio-video data, point-of-care device data and patient medical history data, across hospitals, emergency vehicles and patient portals at home. He is assuring that the IRIS platform will comply with the legislation on privacy and data protection, medical device regulations and liability legislation as well as technological regulations. He studied political science at the Universidad Carlos III de Madrid (2009–2012, including a stay at Maastricht University), European law at the Universidad Nacional de Educación a Distancia (2012–2013) and European Union studies at Maastricht University (2012–2013). He has experience working in institutions based in Spain and Belgium, including the International Automobile Federation, European Digital Rights and the European Centre for International Political Economy.

Chapter 13
Regulation of Medical Digital Technologies

Joris Wiersinga

Abstract M-Health applications may be subject to regulation. Regulatory requirements depend on the geographical area where the application is available, the intended use, and the type of data collected. This chapter discusses medical device and privacy regulation in the US and EU. Most apps will not be regulated. However, if the publisher claims a medical purpose, regulation will apply. The applicable regulations have historically been developed for pharmaceuticals; then adapted to medical devices; and these have been applied to software. As a result, regulatory approaches and software development best practices often clash. Developers should have a strategy to cope with regulatory affairs from the start. This article discusses the most important requirements, gives suggestions for the best way to handle these, and illustrates the approach with practical examples from the Dutch SME SilverFit.

13.1 Introduction

m-Health applications come in many different forms. Some are best compared to self-help books, exhorting the user to lead a more healthy life. The app '1500 + Health Tips' by the company Smart Droidies, for example, limits itself to giving general advice on food, activity patterns and other healthy habits. On the other end of the spectrum, e-Health applications can be used to monitor health parameters, diagnose patients and even propose therapeutic activities or treatments. As an example, diabetes patients can self-monitor their glucose levels and self-administer medicines or adjust their activity using a variety of specialised diabetes apps.

The United States, the European Union and many other countries have created legislation to ensure that medical equipment complies with certain standards. In the offline world, a product that dispenses general health advice would not be regulated; however, a product used to measure glucose levels and treat a medical condition would be considered 'medical'. Such a product has to comply with a large number of regulatory requirements. The most important among these are that the efficacy of the treatment has to be evidence-based, that a risk analysis has to be created and

J. Wiersinga (✉)
SilverFit BV, Woerden, Netherlands
e-mail: joris@silverfit.nl

H.R. Marston et al. (eds.), *Mobile e-Health*, Human–Computer Interaction Series,
DOI 10.1007/978-3-319-60672-9_13

measures put in place to mitigate risks (World Health Organization 2003) and that all data has to be treated as private patient information and enjoys certain protection. The regulation, as laid down by the European Union and the Federal Drug Administration (FDA) in the United States, was developed using principles and methods originally created for the regulation of medicines. These were then adapted to medical devices and, by extension, to medical software. This regulatory approach is very rigorous and assumes a trajectory in which designers move through carefully gated steps towards a fixed end product.

This formal approach contrasts strongly with the daily practice of m-Health applications. Users (formerly known as patients) freely and actively share medical information online with others. They ask questions, share experiences and often provide detailed test data through online fora (such as/r/cancer on reddit.com) or specialised sites such as a Dutch forum for people with ME (https://www.me-gids.net/Forum.html). When and how can others use this data? Most software applications are not written using the rigorous but very slow methods used for medical devices: rather, they are updated weekly or even daily. How should a regulatory system cope with this? If we require an evidence-based validation, what exactly has to be validated? What is the best way to identify and mitigate risks? This chapter will discuss these questions, and the implications for future regulation and m-Health design.

13.2 Regulation of Medical Digital Technologies

13.2.1 Introduction

In many ways, m-Health is a world of two opposites. On the one hand, the medical device industry is a strictly regulated field; development timelines are long; every activity is precisely documented; user testing is only done towards the end of the cycle; products cannot be released unless they conform to all stated requirements; products will be recalled if nonconformity is detected later on; and user data has to be shielded against any privacy intrusions.

Contrast this on the other hand with mobile app development: regulation is much less stringent; development times are short; documentation is as-required; user-centric design requires user testing to be one of the first steps in the cycle; products will be released when they are ‘ready to ship’, with regular patches planned from the start; patches replace recalls; and users freely share their data online with friends, family and large corporates.

The development time of a medical device from concept to first sales depends on a lot of factors. Depending on the type of system and who you ask, estimates range from 3 to 7 years (Steinberg et al. 2015). In contrast, mobile apps take between 3 and 12 months from concept to app store shelf (Crispy Codes 2014). As a result, design specifications, development processes, quality control and many other terms may mean vastly different things to practitioners from either world.

13.2.2 Regulatory Systems

Regulation of medical devices is different on a country-by-country level. Historically, the main regulatory systems have been the FDA (Food and Drug Administration) requirements in the United States, and the CE mark (Conformité Européenne, Medical Device directive 93/42/EEC) used in the countries that form part of the common European market.

Most, but certainly not all other countries historically adhered to guidelines that were very similar or lacked guidelines altogether, so that FDA and CE compliance more or less predicted acceptance in other geographies, at least for simpler devices. Getting accepted in all geographies would still sometimes require local paperwork, but most of the time did not lead to additional underlying requirements such as additional tests, adherence to local environmental rules, or other adaptations that require changes to the product itself. Since about 2014, Chinese regulators have become more assertive. Given the growing importance of the Chinese market, this possibly means global players will have to focus on at least three major regulatory systems in future.

Each of these regulatory regimes advices and in certain cases prescribes a lot of documentation and an adherence to standards with regard to things like risk and quality management. In practice, the standards used are those set by the IEC and ISO organisation. ISO guidelines can be pretty hard to interpret, as they normally cover specific areas and reference other ISO guidelines for context or adjacent topics. In addition, there are separate regulations for handling personal data (mainly relevant in the EU) and medical data (all geographies).

13.2.3 Most Apps Are Not Regulated

From the point of view of the developer, it is normally good news that many health-related software applications are not classified as medical devices and therefore not subject to the stringent regulation associated with such devices. For consumers, this can come as a surprise. The expectations of consumers with regard to regulation seem not to have been researched in depth; their ability to adequately use online and mobile resources, often referred to as e-Health literacy, has received more attention. Although the use of e-Health resources is common, many people struggle to find the right information as they lack the relevant skills (Van Deursen and van Dijk 2011), and this is even true for many people living with chronic diseases (Van der Vaart et al. 2013). e-Health literacy consists of many factors; whereas older people often lack (or lacked) practical skills, both young and old participants find it hard to adequately judge the quality of information and assess the privacy impact of sharing their information online (Van der Vaart et al. 2013).

As an example from medical practice, one patient was quite surprised to hear that Wikipedia was not regulated in any formal way—he only found out a week after

opting to get an eye operation, a decision he had based on reading Wikipedia after getting conflicting advice from people in his (offline) social network. The information itself in this instance turned out to be correct *(pers. comm.* by the physician).

Although this can be a real challenge for consumers, with regard to the quality of information, the online situation is perhaps not too different from that offline world: there is no regulatory oversight on the quality of health advice provided daily by many magazines and popular books either. Nevertheless, it may indicate that from the point of view of the general public, there is probably too little, not too much regulation of medical apps.

13.2.4 A Short History of Medical Device Regulation

The medical profession has probably always suffered from unqualified people prescribing useless or harmful medicines and therapies. Bad doctors have been the focus of government regulation for centuries (Raach 1944). After serious incidents with diethylene glycol poisoning in the United States in 1936 and thalidomide (DES)-induced miscarriages in Europe between 1958 and 1960, governments also stepped in to regulate the development and safety of medicines (Rägo and Santoso 2008). In the United States, the Federal Drug Administration (FDA) was created for this purpose. In Europe, regulation was originally done at a country-by-country level, and then harmonized across the European Union in the 1990s.

In the United States, medical devices were regulated under the same rules as medicines until 1976; since then, they have gradually received differential treatment. Most of the regulation is governed by the FDA. In essence, they require the producer of a medical device to comply with certain requirements and provide documentation to the FDA. Software, and therefore apps, is seen as a special class of medical devices.

European rules for medical devices have also evolved from regulations originally created for medicines. In the European Union, the medical device directive 93/42/EEC governs most medical devices (in vitro diagnostic devices and active implantable devices have their own directives). The medical device guidelines form part of a broader European system called CE. It is said that CE originally stands for Conformité Européenne, or 'European conformity', but official documents always refer to the 'CE mark' without explaining this (probable) historical origin. CE marks are required on a large number of products that may provide safety hazards, such as toys, electrical equipment, elevators or safety equipment. Again, it requires manufacturers or importers to comply with certain rules and provide documentation of that compliance, or, in some cases, provide a statement that such documentation is available for inspection by the authorities.

13.2.5 When to Consider Regulation as a Developer

If an app falls under one of the regulatory systems described below, this can have serious repercussions on the design, development process, technical standards and documentation requirements. It is therefore wise to consider before starting to design or develop an app, whether it will be regulated. It is much harder to do so after development has been completed.

The most relevant questions to ask are:

- In which geographies will the app be used?
- What type of medical practitioners will be involved either as a customer or in another role?
- What type of use will you advertise in marketing materials and in the app itself?

These questions of course are also of vital importance to guide the overall business plan and product design. The advantage of considering regulation at the start is that it is still possible to adjust either the business plan or the development process, based on the commercially and legally required and acceptable levels of regulation.

As a first step, it is almost always useful to consider whether it is possible to focus the business plan so as to remain outside of the regulated realm. This can be done by carefully wording the intended use (in all marketing materials, speeches, software text!) and avoiding certain regulated use cases and users. If regulation is inevitable, it often makes sense to limit the intended use to low-risk situations which carry a lower regulatory burden.

Painting with a broad brush, the FDA regulations exempt a lot of medical software and apps from being regulated as medical devices. Many US developers purposefully design software in such a way that they do not fall into a regulated category. It is important to note that this type of consideration should be made separately for each regulatory regime: what is exempt in the United States will not necessarily be so in the EU.

It may also make sense to evaluate at the start of your development whether your customers will demand certification or not. In Europe, the stringency with which CE norms are enforced still seems to differ between geographies. Potential customers such as hospitals and other care providers have started to be more demanding with regard to CE certification of products—but it is still very common to see non-medical device home trainers and treadmills in physiotherapy practices and hospitals. The same is undoubtedly true for software. Buyers, sellers and developers are often painfully, or blissfully, unaware of the regulatory requirements.

Commercially, the CE certification seems to be very valuable when exporting products from the EU to other countries, excluding the United States. Almost every Asian partner will ask for ISO and CE certification as a matter of course. In some cases, this can provide serious obstacles: products that are not classified as medical devices by definition cannot be CE (or FDA) certified as such, and this can be a serious commercial drawback when selling outside the EU. As an example, I have

personally spent a full day discussing with an Asian reseller the impossibility of obtaining an approval by a notified body of a class I medical device. Class I devices are self-regulated, and the only 'proof' you get for completing a file full of documentation is a letter stating your certification request has been administered. It is impossible to request the government to further certify your product. Nevertheless, our Asian partner needed more official documentation in order to satisfy their customers. It is perhaps the only time that, as a developer, I actively wished for more certification procedures!

13.3 The Situation in the United States

13.3.1 Which Apps Does the Federal Drug Administration Regulate?

The Federal Drug Administration (in collaboration with the Center for Devices and Radiological Health and the Center for Biologics Evaluation and Research, two other regulatory bodies) has published an excellent nonbinding guidance paper on mobile medical applications which clarifies its position on mobile medical applications (US Department of Health and Human Services, Food and Drug Administration (et al.) 2015). It states that the majority of mobile apps currently on the market either do not qualify as medical devices, or pose such a low risk to patients that medical device requirements will not be enforced. This broadly follows the policy set out for nonmobile software and online applications.

Developers of mobile apps should always seek specific guidance with regard to the regulatory requirements of their application, based on the most current regulatory information. The following is not intended as a substitute for doing so, but as a short primer. In a nutshell, to determine whether an app is a regulated medical device, the Federal Drug Administration (FDA) looks at intended use: the way the manufacturer intends people to use the app, as evidenced by labelling, advertising materials, or other public communication by the manufacturer or their representatives. The actual use may be different—a product intended for medical purposes can be used outside the medical sphere and still be regulated; and a product intended for non-medical use does not become regulated if a user decides to employ it in a medical setting. It is thus possible in theory to have two identical products with different advertising materials, only one of which will be regulated.

Apps that do one of the following are considered regulated devices by the FDA:

- Connect to another medical device to control it, monitor patients, or analyse medical device data, for example, an app to control inflation and deflation of a blood pressure cuff.
- Use attachments, display screens, sensors or provide functionalities similar to that of regulated devices, for example, attachment of a blood glucose meter.
- Perform patient-specific analysis and provide patient-specific diagnosis or treatment recommendations, for example, use patient-specific parameter and calculate dosage for radiation therapy.

The FDA states it will exercise 'enforcement discretion', meaning it does not intend to enforce regulation, for apps that:

- Help patients self-manage their condition without providing specific treatments or suggestions. Example: promote strategies for staying fit.
- Provide patients with simple tools to track information. Example: log, track and trend drug intake times.
- Provide easy access to information related to patients' health conditions or treatment. Example: lookup table for best practice guidelines for common illnesses.
- Help patients document, show or communicate potential medical conditions to healthcare providers. Example: app to use a phone's camera to transfer pictures of a wound to a doctor.
- Automate simple tasks for healthcare providers. Example: calculate BMI.
- Enable patients or providers to interact with Personal/Electronic health record systems.
- Are intended to transfer, store, convert format and display medical device data in its original format from a medical device. Examples are 'second screens' that do not fall under the category of regulated devices above.

Apps that are explicitly not considered medical devices include:

  - Electronic 'copies' of textbooks
  - Educational tools for medical training
  - Apps for general patient education, which do not intend to diagnose or provide treatment suggestions.
  - Apps that automate general office operations in a healthcare setting. Example: shift planning for doctors.
  - Mobile apps that are generic aids. Example: a magnifying glass app (US Department of Health and Human Services, Food and Drug Administration (et al.) 2015).

13.3.2 Federal Drug Administration Medical Device Classes

If an app is regulated as a medical device, the next question is if it is a class I, II or III device. The regulatory level depends on the risk associated with using the device. For class I devices, only 'general controls' are required. These are however already quite stringent and include, for instance, the requirement for using a quality system. A quality system governs not just the product, but the entire organization; it requires you to have a documented and standardized approach to running business processes such as hiring and training people, gate-staging decisions, etc.

Class II devices in addition require special controls, which depend on the device type, as well as a different notification procedure. Examples of special controls include performance standards, post-market surveillance requirements, patient registries, special labelling requirements and pre-market data analysis requirements.

Class III devices require upfront pre-market approval by the FDA. Devices are classified as class III if they are implantable, and/or have catastrophic effects if they fail, and/or are so new that risks cannot be determined. Therefore, most apps will not be class III devices.

The FDA website contains a database with examples of products and their classification. This can be a good tool to assess the probable classification before seeking specific guidance.

13.3.3 US Data Protection: HIPAA (Health Insurance Portability and Accountability Act)

In addition to the FDA medical device regulation, some applications will need to comply with data protection law laid down in HIPAA Title II (Health Insurance Portability and Accountability Act—but no one ever calls it by its full name). This act governs the security and privacy (including disclosure) of patient information in a section that has received the somewhat Orwellian title 'Administrative Simplification Rules'. HIPAA sees to patient data processed by so-called covered entities. The CMS (Center for Medicare & Medicaid Services 2016) has developed a useful tool to determine whether an entity is covered under HIPAA. In short, if a US entity provides healthcare services and processes data electronically, it is probably a covered entity. Any business associate (such as people developing an app for a covered entity) also falls under HIPAA rules.

HIPAA has rather stringent rules about who can see a person's medical records. All 'individually identifiable health information', that is, all information that can be linked to a specific individual, is considered protected health information (PHI). For example, if a doctor would prescribe an m-Health app that sends back any information about the patient—even if only the patient's weight or daily activity—this would be considered PHI.

Protected health information (PHI) can be disclosed to third parties only in a limited number of cases specified by HIPAA. Although it is possible to obtain consent for disclosure, this consent needs to be specific as to the information disclosed and who it will be shared with. This severely limits the ability of app makers involved in a direct way with professional healthcare providers to do things such as:

- Incorporate social media.
- Monitor individual usage statistics to improve the app.
- Use app data for research.
- Monetize the data gathered by the app.

In addition, the so-called security rule regulates the way PHI data has to be stored and secured. In practice, a number of specialised service providers have stepped in to provide HIPAA-compliant data services. These are quite user-friendly (to a developer), although more costly than non-compliant services. Unfortunately, it is not easy to comply with both HIPAA and EU data regulations using the same service, as both systems somewhat anachronistically require data to be stored in their

respective geographies. This leads to some complexities when developing global products; however, these requirements are much less burdensome than those imposed by the privacy rule, as they can normally be tackled by technical means.

Information not covered by HIPAA is subject to standard data privacy laws; these are much less stringent in the United States than in Europe. Consent given by accepting general conditions at installation is normally considered sufficient. Note that this type of data may include very private medical information, as long as no covered entity (such as a doctor) has been involved in creating, processing or sharing the information.

13.4 The Situation in the European Union

13.4.1 What Is Regulated by the European Medical Device Guideline?

The European medical device guidelines have a similar structure as the ones used by the FDA; however, there are a lot of small but potentially very relevant differences.[1] One unfortunate difference is that the EU regulator is much less forthcoming with providing easy-to-understand, practical guidelines. The official guidelines that are available are less easy to read than their US equivalent (European Commission 2016).

This void has been filled by specialised CE mark consultancy firms. Perhaps as a result, most available guidelines for CE marking leave the reader somewhat baffled, and likely to call the consultancy firm for further guidance.

Before evaluating if an app falls under the medical device guideline, it is relevant to check if it is to be considered 'stand-alone' software. Software that is linked to another medical device, for instance, to control or monitor it, may be considered part of that medical device or an accessory of that medical device. This automatically classifies the software in the same class as the main device. It is allowed to create an interface between regulated and nonregulated (or less highly regulated) devices or even between two separate pieces of software (modules). This can be a very useful way to prevent full-blown regulation on every aspect of the software. However, it does require careful design and quality assurance of the interface between the regulated and the nonregulated devices.

Similar to the US situation, the CE regulation considers the 'intended use' of the software: what the manufacturer says the software is for, rather than what the software is in fact used for. Software is regulated if it:

- Is intended to diagnose, monitor, treat or alleviate human diseases, injuries or handicaps

[1] Recently, new regulation has been confirmed as of 2020; this chapter does not yet fully reflect those changes.

- Is intended to investigate, replace or modify part of the anatomy or a physiological process
- Is intended to control conception

If the intended use is not medical in nature, the software will generally not be considered a medical device. Specifically, the following are not considered medical devices:

- Software that only performs simple actions on data (storage, archiving)
- Software that does not perform actions for the benefit of specific patients

Unlike in the United States, there are no categories of apps for which regulation is 'not enforced'. However, the requirements for the lowest CE class (class I) are relatively easy to comply with—although still a lot of work!

13.4.2 CE Medical Device Classes

The CE system uses subclasses as well as classes, which makes the initial classification slightly more complex than the three classes used in the United States. The classification rules are detailed in Annex IX, Part III of the Directive. There are a lot of useful flowcharts online that can help you through the classification steps (e.g. http://www.ce-marking.org/Guidelines-for-Classification-of-Medical-Devices.html).

Under the CE system, software is automatically classified as a so-called 'active' medical device. This means that of the 12 main rules in Annex IX, rules 9–12 are applicable. Rules 9–11 provide a number of specific cases of devices that fall into classes IIa and IIb: Rule 9 considers any device that applies energy to the body, or controls or monitors a device that does this; rule 10 considers devices used for certain forms of diagnosis; and rule 11, devices that are concerned with controlling or monitoring the uptake of medicine or the removal of bodily fluids. Cases that do not fall into these categories are classified as class I. Within class I, there are special rules for any device that has a measurement function or sterile components. Technically, there is also the possibility that the app falls under a different directive if it is used for in vitro tests—but most apps will not fall into this category.

As mentioned above, if an app is used to monitor or control another medical device of a higher class, it does not count as stand-alone software and will take over the classification of that device.

13.4.3 Data Protection in the European Union

The EU has privacy regulation covering all use of personal data, not just medical use. For now, this is governed by the data protection directive (95/46/EC). The EU Agency for Fundamental Rights has developed a useful handbook which covers all the rules (EU Agency for Fundamental Rights and Council of Europe 2014).

From 2018 onwards, personal data will be governed by the General Data Protection Regulation (Regulation (EU) 216/679) or GDPR. This regulation covers anyone processing personal data, whether on paper or electronically. Most things you may want to track are covered and thus regulated: names, addresses, health data, fitness performance data, food intake and shopping habits, for example, would all fall under this regulation. Even game high scores might be covered if they can be traced back to an individual person.

The GDPR requires that data be collected and processed based on lawful grounds. In practice, for most apps this will mean explicit consent. The GDPR provides rules on how consent should be given and how it can be withdrawn. Consent should be given for the specific use of the data. Default privacy settings should be maximum, so that participants always 'opt in', not 'opt out' of sharing data.

The GDPR also provides rules on how to store and protect the data; specifically, you may not export the data outside the EU unless you conform to certain guarantees.

Finally, the GDPR provides a number of procedural rules, including (of course) a lot of required documentation. Special procedures need to be in place in case of a data breach that may pose a risk to the parties concerned. A dedicated Data Protection Officer (DPO) has to be appointed if you exceed a certain threshold of personal data processed. The DPO has to have an independent role in the organization (they can even be external). He or she needs to monitor compliance, ensure documentation of procedures, and manage complaints. At the moment, there is no formal qualification requirement for the DPO, but this may change in future.

Medical data are not treated the same as non-medical data. Article (35) of the GDPR defines medical data as 'all data pertaining to the health status of a data subject which reveal information relating to the past, current or future physical or mental health status of the data subject'. This includes all information about admittance or treatment by healthcare providers but also 'information on, for example, a disease, disability, disease risk, medical history, clinical treatment or the physiological or biomedical state of the data subject independent of its source, for example from a physician or other health professional, a hospital, a medical device or an in vitro diagnostic test' (Article 35 GDPR).

The GDPR sees health data as especially sensitive. Article (53) says this data may only be used for the benefit of the person or society; in most cases, this means only persons subject to a legal obligation of professional secrecy may access the data. It is allowed to use anonymised data for scientific research, if informed consent has been obtained. See (Hordern 2016) for a readable discussion of other requirements.

This area of regulation is quite volatile. Privacy activists and social network companies are still debating the exact interpretation in and out of court. It is also not yet clear how severely each of the requirements will be enforced, although the stated objective is to become stricter—the rules allow for quite a strict enforcement regime. European governments are increasingly worried about the potential privacy infringements by 'Big Data' corporates, many of which are based in the United States. At face value, many of the data management practices currently common in social apps may be or may become illegal. As is the case with HIPAA compliance in the United States, service providers will likely emerge that will help store and process the data

in a way that ensures regulatory compliance, so that the app maker can mostly focus on the customer side of things.

13.5 Practical Implications

13.5.1 Help! I'm Making a Regulated Device

If it turns out your app is a regulated medical device, this has a number of consequences. Some of the requirements for medical devices make a lot of sense. For others, the best that can be said is that during a dinner party, they trump most other anecdotes on superfluous regulation. As an example, our company SilverFit has developed a video app allowing elderly people in care homes to cycle on a home trainer watching a video of their home town. This video application is classified as a class I medical device, and as such, we have had to develop a procedure to warn the Ministers of Health of all member states in case of a medical emergency caused by our app that may impact the public health—the procedure is operational 24/7 and all company employees have to be instructed. It may be of use should one of our elderly participants spot an unnoticed zombie invasion on one of the video recordings….

A number of advisory firms can help developers navigate through the regulatory steps. This can help create the semblance of compliance (at a minimum, you will have a lot of documents in a binder), and, if done well, can be a good starting point for true compliance. Personally, for the EU I would advocate being closely involved with the key steps in the regulatory process and using pre-made templates only for fringe requirements (such as the procedure for warning all ministers of health. In our company, SilverFit, pre-made templates never elicited any response or change to the underlying product. We therefore stopped using them after we had launched the first three products.

By contrast collaborative workshops on specific areas did often lead to significant improvements. As an example, we organize risk identification and mitigation workshops. In a risk identification workshop, we bring together developers, clinicians, quality assurance specialists and if possible customers to identify potential risks. The 'official' approach is to use a very long checklist—however in practice we see that the most pressing risks are not included on the checklist, whereas many completely irrelevant items had to be considered. As an example of the type of risks that can occur, one of SilverFit's products lets people exercise by themselves as part of their rehabilitation process. It has an alarm clock function that tells you when to exercise. This alarm clock uses the computer's inbuilt clock, which unfortunately relies on internet connectivity. If the system is not connected to the internet, the computer's clock may be off, leading to an alarm in the middle of the night, which can easily cause falls if people try to get out of bed by themselves. No checklist would surface such a risk, but a workshop can. The support of an advisor (and some checklists) at the same time has been essential to make sure the overall documentation was complete.

The FDA and the European National Inspections (ENI) are often quite open to answer questions, which can be extremely useful. They are also, in general, very well aware of which regulations make sense and which do not and adjust their inspection focus accordingly. In the Netherlands, where our company SilverFit is based, one can find contact information easily on the website of the Inspectie Volksgezondheid (Inspection for Public Health).

In the EU, the most likely classification an app will end up with is class I. Class I devices are self-regulated. The manufacturer has to compile a technical file; the software has to be labelled following certain rules (93/42/EEC Annex I point 13) in the local language (93/42/EEC Article 4(4)), and the CE classification has to be filed with a national authority. The involvement of the national authority is different from country to country. In the Netherlands, it is done by the Inspectorate for Health. At SilverFit we have consistently had questions or audits following the declaration of class I products, but this is not necessarily common practice.

The technical file contains a number of elements that are very useful, even for nonregulated products. Two of them can be easily created through collaborative workshops:

- A statement of intended use. As noted above, this determines the classification. The intended use has to be consistent in all communication about the device. Best practice is to have a dedicated person check all outgoing marketing materials and software texts with an eye to compliance with the intended use.
- A risk file. For our products, this has been the single most useful tool. It consists of an exhaustive list of potential risks; each risk is classified according to incidence (how likely is it?) and severity (how much damage will there be). All unacceptable risks should be prevented or mitigated. We create these risk files using a number of sessions with experts from different disciplines and users. Doing the analysis multiple times during development can greatly help steer the product in the right direction. A yearly update of the risk file is required during the product's lifetime.

Another requirement that takes a bit more time but will turn out to be very useful is tracking installations and issues. You need to have a system to track installations, including different versions. The system also needs to track issues arising from these installations, and of course you need a method to address these issues and track your improvements. Note that this kind of tracking is specifically allowed under the EU privacy regulations.

The technical file also contains two more elements that are very important, but more difficult to conform to in the case of software: a set of documents that detail design and verification and documentation of validation. The developer is required to provide a design, as well as a verification procedure that checks if the final product conforms to the original design. This is covered in a guideline called IEC62304, which is accepted both by the FDA and the CE system.

To people not versed in software development, this requirement sounds logical enough. However, this way of design thinking does not sit well with modern software development practices. Modern software companies almost universally aspire

(though they do not always succeed) to use 'Agile' development processes. Whereas old-fashioned processes prescribed a detailed design of the entire product upfront, 'Agile' recommends designing pieces of software in little steps. Each succeeding iteration of the prototype product will teach users about the flaws in the design so far. 'Agile' has been proven to be much more effective as a software design method than the traditional 'waterfall' approach (this approach was named for the Gantt charts it produces, which look a bit like a waterfall). However, it is hard to reconcile an 'Agile' process with the design first—then build—then check philosophy of the regulator.

There are basically three ways to save your development process and still comply with the guideline (but see (MD101 2012) for a lot more nuances):

- Try to start with a full design phase; then work using Agile as much as possible while updating all documentation and performing tests on the way; then do a full verification at the end of the process. The issue is that you often do not know user requirements, software specification or architecture at the start of the process. You will be spending a lot of time rewriting documentation when using this method.
- Start with a high-level, more abstract design phase, then proceed with Agile development. At two or three points during the process, spend a serious amount of time on refining the documentation (requirements, specification, and architecture) for all elements that are completed. Provide a full verification at the end of the process.
- Use Agile methods during the entire development phase, then create all documentation at the end of the process and validate against it.

A legal problem when doing user testing is that EU law considers most testing of a medical device to be a clinical trial (Annex X of the directive). This means a protocol has to be established beforehand; the process has to comply with ethical standards (Annex X 2.2). In the Netherlands, this means the protocol has to be approved by an external medical & ethical committee (METC). These are linked to major universities and hospitals. Any company can propose a research protocol for their consideration—but of course the step consumes time and budget. Also, it is hard to reconcile with Agile principles.

For the initial development, any of these methods can function well. However, the same process must be followed for subsequent updates. This can severely limit your ability to improve the software. Although small patches can be incorporated as add-ons to the technical file, providing regular updates under a regulated regime may place too much of a burden on quality control and documentation.

In addition to these 'difficult' requirements, there are a number of rules regarding things like archiving and emergency procedures, etc. that can easily be complied with by using appropriate templates. Some apps may have to comply with additional regulation, e.g. around electrical safety, correct measurement or specific requirements for certain medical devices.

Products in higher classes also follow different procedures with respect to the FDA or CE approval process, with more stringent and lengthier checks. Companies

manufacturing more high-risk classes of medical applications (including enforced class I FDA) have to subject their overall company processes to ISO certification. This involves not only the product development, but other processes such as HR, training and sales, etc. ISO certification takes a minimum of 12 months and normally longer.

13.5.2 Validation of Medical Software

Interestingly, regarding the actual validation of software, the question: does it work? is only a small part of the overall regulatory file. It is vital yet this is the step most people unfamiliar with the actual requirements, expect to take place. Again, the FDA has provided a nice overview in a guideline (FDA 2002).

The developer has to document that the working principle (as evidenced in the technical file) has the medical outcomes as described in the intended use. In other words, he has to prove (or at least document) that the product works. As before, you only have to prove what you claim; if this is hard to do, then it may be wise to claim what you can prove. The intended use (see above) forms the core of this claim; it should be supported by a document that explains the working principles.

In some cases, proving the claim is relatively straightforward. In many cases though, it will require a careful approach and serious clinical trials. In cases where proving the ultimate effect of an app is difficult, researchers often look for proximate outcome measures—e.g. instead of measuring the effect of a fall prevention app on the number of falls, they measure the impact on self-reported fear of falling. Naturally, this should be reflected in the claims.

In terms of regulatory requirements, the level of evidence required depends on the class of the medical device. The medical device guidelines have been derived from practices common in developing pharmaceutical interventions and thus see randomised controlled trials, or RCTs, as the gold standard. These are not always easy to apply to software development (Van der Kooij et al. 2015).

There has been a lot of debate, for instance, on how to test the efficacy of medical apps that claim to work through changing users' behaviours. Many 'games for health' and 'fitness trackers' fall into this category (although as we have seen, such apps are not necessarily regulated). In a pharmaceutical RCT, the population you study is randomly split into two groups. One group receives the medicine, while the control group receives a placebo. A key difficulty when working with software is this second group: what kind of placebo should they receive? Researchers have tried to create 'placebo software', but as the user inevitably notices the difference between the real thing and the placebo, this is a very difficult proposition. Others have compared using the software to 'treatment as usual'. This may underestimate the impact of receiving a new/different treatment.

It is often difficult to determine the timeframe in which behavioural change will take place (Van der Kooij et al. 2015). Behavioural change is a complex process, and it may be hard to pinpoint the effect of an app in the short timeframe of a typical

study. The actual change can occur (long) after the moment of self-reflection or insight provided by the game. Again, many researchers revert to measuring proximate outcome effects (do you know smoking is bad for you vs. did you stop smoking).

The Dutch Society for Simulation in Healthcare has developed an international Quality Label for validated games for health; their focus is on health education games, but the label is not limited to such games. The developer can provide documentation to the society. It consists of chapters that sound familiar by now: description, rationale, functionality, validity and data protection. A group of independent medical experts review the documentation (Dutch Society for Simulation in Healthcare n.d.). It remains to be seen whether this—to my knowledge—first Quality Label will become important in the market. Undoubtedly though, this type of certification will become more important or even required in future.

Validating a software device is a costly and lengthy process; this means it is very unlikely that it can be repeated for later updates. It may be prudent to validate certain core working mechanisms of the software (the EU regulations are more favourable to this than the FDA) and keep these stable over time. Updates can be focused on areas that do not change the core effectiveness of the app.

13.5.3 Some Practical Examples

Our company, SilverFit, has over time developed different products, both regulated and unregulated. It may be instructive to share our approach and experiences here.

First, we always consider carefully whether a product has to be sold making any medical claims. Our product SilverFit Alois, for instance, has been developed to provide leisure activities for people living with dementia. Although the cognitive and physical activities that we provide may have health benefits, there is no specific diagnosis, treatment objective or measurement of outcomes. In addition, we do not sell this product outside the European Union, and our European customers, residential care homes and day centres are not required to only use systems that comply with the medical device guidelines. So, we decided not to go through the CE process. We still used key components of the CE process, such as the risk analysis, to improve our product.

On the other side of the spectrum, our product Rephagia is used to treat swallowing disorders in frail elderly people. In this case, there is a very clear medical objective—and we claim medical outcomes. In addition, the treatment carries certain risks, as incomplete swallows can lead to pneumonia, a life-threatening condition for our patients. The system therefore had to be classified as a medical device. The measurement part, a surface electromyography (sEMG) sensor, was classified as a class II device by our manufacturing partner. They provided an API which fully shields the behaviour of the sensor from our software. As a result, we were able to classify the software as class I, allowing us to more rapidly update the software

component while keeping the patient-linked physical component completely stable.

Another product, the SilverFit Mile, falls in between these two extremes. It provides video images for people cycling or walking on a treadmill. Two customer groups, European hospitals on the one hand and Asian distributors on the other, demanded medical device certification. At the same time, our medical claims for this product are very limited: at the time, we only claimed to make the exercise more motivating (we have since added some claims based on further research). The National Inspection (of the Netherlands) visited us to inspect our documentation and advised us that medical certification would not be required for this product based on our claims—however for commercial reasons, we kept the certification intact.

For our very first product, the SilverFit Mile, we worked with an external advisory company; they provided us with a checklist of all required documentation and templates for each of the documents. We used these templates to provide 'legal' documentation—still a lot of work as our technicians had to provide the consultants with all of the relevant details. A year later, the National Inspection announced they would like to visit us, as they were working on refining (or defining) their requirements for medical software. To prepare for this, before the visit we quite thoroughly reviewed our documentation and decided to redo all documentation that we ourselves did not understand but felt was important: the essential requirements, product documentation and risk file being the key components here. As a result, we also implemented the risk workshops described above. For all subsequent products, we have used this mix of 'formal' and 'accessible' documentation.

From the beginning, our development team has been impacted by the regulatory demands as the software architecture and functionality has to be documented. Although this is good practice in general, few developers enjoy the process and so it is often put on the backburner. Over time, we have improved the quality of our design and build and test documentation. This has obviously also been very useful when adding more and more team members and revising existing products. To be fair, a lot of software documentation is still done afterwards, although we strive to bring this process forward as much as possible.

Our operations team has also been impacted by regulations from the very start, mainly because we have required them to document every customer interaction and all available details on hardware and software installations at the customer's site. This means we can track exactly when and where problems occur, and it has been extremely helpful to improve our products over time—but most of our technicians still really dislike the database logging that is required to keep this information up to date.

As our company grows, we have had to implement checks to ensure we do not accidentally make medical claims in our brochures or on our website that go beyond the medical claims in our documented intended use. For this reason, we have developed a quality control procedure for all of our marketing materials.

Regulatory matters have also sometimes impeded growth; for example, we built an 'advisory app' that helps physiotherapists find the right exercise for their patient.

In Europe, it can be used and is very popular; but in the United States, it would bump the application into a different regulatory regime, and as a result, we have decided not to apply it there. We have had similar experiences when building functionality that tracks a patient's performance: US and European rules differ quite a lot so that two separate designs and implementations are required to serve both geographies. Obviously, this leads to a lot of rework.

One of the most difficult things regarding the regulatory regime is not to lose the fast, user-centred innovation that makes software companies so successful. Shipping or even user testing something that may fail can be risky and/or illegal. At the same time, the best (and perhaps the only) way to develop useful software is to put it in front of actual users as soon as possible. We believe that in many cases, the risk of doing so can be mitigated by using tools taken from the regulatory approach, without going 'all the way'. The current legality of such an approach is not always clear, and in our view software developers, regulators and especially patients could benefit tremendously from a more practical approach in this respect.

13.6 Conclusion

The development of medical apps has in many ways been force-fitted into the regulatory straightjacket originally created for pharmaceutical research and later adapted for medical devices. In practice, the straightjacket provides more room for manoeuvre than at first seems to be the case. In many cases, it can be avoided altogether. In some cases, obtaining a regulatory seal of approval can be commercially vital.

Although some of the steps are tedious regulatory requirements, many of the core components of the regulation are very useful. The most important discrepancy is that the regulatory world assumes a design process that has become completely outdated. Unfortunately, this design process is at the very heart of the regulatory structure. It would be very unwise to use the 'ship-then-fix' mentality of modern software development for products upon which your life may depend one day. Neither is it desirable that medical software stays stuck in the Stone Age. It would be a great contribution to develop a regulatory approach that can cope with the new design practices without jeopardising patient safety.

References

Center for Medicare & Medicaid Services (2016) CMA Covered Entities Chart 2016. Accessed September 7, 2016. https://www.cms.gov/Regulations-and-Guidance/Administrative-Simplification/HIPAA-ACA/Downloads/CoveredEntitiesChart20160617.pdf

Crispy Codes (2014) How much time it takes to create a mobile app. January 14. Accessed September 5, 2016. http://www.crispycodes.com/blog/mobile-app-development/how-much-time-takes-create-mobile-app.php

Dutch Society for Simulation in Healthcare (n.d.) Quality Label Serious Games in Medicine. Accessed September 1, 2016. http://www.dssh.nl/en/quality-label/
EU Agency for Fundamental Rights and Council of Europe (2014) Handbook on European Data Protection Law
European Commision (2016) MEDDEV 2.1/6 Medical Devices Guidance Document: Qualification and Classification of Stand-Alone Software. Legal Guidance Document
FDA (2002) General Principles of Software Validation; Final Guidance for Industry and FDA Staffs
Hordern V (2016) The final GDPR text and what it will mean for health data. 20 1. Accessed September 1, 2016. http://www.hldataprotection.com/2016/01/articles/health-privacy-hipaa/the-final-gdpr-text-and-what-it-will-mean-for-health-data/
MD101 (2012) How to develop medical device software with agile methods? Accessed September 1, 2016. http://blog.cm-dm.com/post/2012/05/12/How-to-develop-medical-device-software-with-agile-methods
Raach JH (1944) English medical licensing in the early seventeenth century. Yale J Biol Med 16(4):267–288
Rägo L, Santoso B (2008) Drug regulation. History, present and future In: van Boxtel CJ et al. (eds) Drugs benefits and risks: international textbook of clinical pharmacology, revised 2nd edition, pp 65–77
Steinberg D et al (2015) Building a business model in digital medicine. Nat Biotechnol 33:910–920
US Department of Health and Human Services, Food and Drug Administration et al (2015) Mobile Medical Applications, Guidance for Industry and Food and Drrug Administration Staff
Van der Kooij K et al (2015) Validation of games for Behavioral change: connecting the playful and serious. Int J Serious Games 2(3):63–75
Van der Vaart R et al (2013) Measuring actual eHealth literacy among patients with rheumatic diseases: a qualitative analysis of problems encountered using Health 1.0 and Health 2.0 applications. J Med Internet Res 15(2) feb: Published online 10.2196/jmir.2428
Van Deursen AJAM, van Dijk JAGM (2011) Internet skills performance test: are people ready for e-health? J Med Internet Res 13(2) apr-jun: Published online 10.2196/jmir.1581
World Health Organization (2003, Geneva) Dept. of Blood Safety and Clinical Technology, Medical device regulations: global overview and guiding principles

Joris Wiersinga is the co-founder and CEO of SilverFit (www.silverfit.nl). SilverFit develops and markets virtual rehabilitation software: computer games to help treat people with stroke, dysphagia, breathing problems, dementia, and other pathologies by guiding them through relevant exercises. SilverFit has developed 9 products and is active in 19 countries. Before SilverFit, Joris worked as a consultant at McKinsey & Company with a focus on high tech operations and ports. He studied biology and law at Leiden University and holds an MBA from INSEAD. In his free time, he likes to design, play and publish boardgames.

Part VII
Conclusions

Chapter 14
Transcendent Technology and Mobile eHealth

Charles Musselwhite, Shannon Freeman, and Hannah R. Marston

Abstract Technology is becoming a common place in the lives of all of us, the potential for it to help deliver health and social care is exciting. However, the full potential of this won't be recognised if there is a failure to understand how such technology is interwoven within our daily lives. It must be remembered not everyone can interact with technology in the same way. Yet technology is often developed around the lives of the imagined average citizen, meaning many people can be disadvantaged by not having technology fit their into lives. Systems are still designed to help others in a rather paternalistic fashion. Therefore more needs to be done to involve the end users of the technology in the design of technology such as mobile ehealth (mhealth) and move towards a bottom up transcendent rather than technocratic approach to technology. In addition, there should be more space for understanding how technology, such as mhealth, can change society, examining how it challenges moral dilemmas and ethics. Regulation is important when developing new technology, but it needs to cover changes in practice not just the technology itself. Mobile ehealth also effects many current debates in the lives of older people and those in marginalised groups of society, including challenging systems of health and social care but also housing, transport and economics. More research is needed in the area of mhealth but the research must continue to be multi-disciplinary and fully involve stakeholders and end-users for full potential to be realised.

C. Musselwhite (✉)
Centre for Innovative Ageing, School of Human and Health Sciences, Swansea University, Swansea, UK
e-mail: c.b.a.musselwhite@swansea.ac.uk

S. Freeman
School of Nursing, University of Northern British Columbia, 3333 University Way, Prince George, BC, Canada
e-mail: shannon.freeman@unbc.ca

H.R. Marston
Health & Wellbeing Priority Research Area, School of Health, Wellbeing & Social Care, Faculty of Wellbeing, Education & Language Studies, The Open University, Milton Keynes, Buckinghamshire, UK
e-mail: hannah.marston@open.ac.uk; marstonhannah@hotmail.com

H.R. Marston et al. (eds.), *Mobile e-Health*, Human–Computer Interaction Series,
DOI 10.1007/978-3-319-60672-9_14

14.1 Current Issues with Mobile eHealth

Technology has become entwined in the lives of persons of all ages, in countries across the globe. Information and communication technologies (ICT) connect individuals globally in just seconds, enabling actions previously not possible and supporting families and friends to stay connected via social media and programmes such as Skype, FaceTime, Appletime and WhatsApp. The unprecedented growth in social media supports education and training and allows for a virtual environment for recreation and fun.

These technologies are becoming so powerful that it is becoming hard to live a life without them; we design our society around them. However, not everyone is able to interact with the technology in the same way, meaning people are at a disadvantage to others. It is our failure to understand life, not technology, which is causing this disadvantage. Technological systems are most often designed to support or enhance lives of the average citizen and quite frequently for the average, well-paid, individual living in a high income country. When systems are designed outside of this, the technology is then typically designed with a notion to change, challenge or improve the lives of these people, as if they only live their lives in deficit.

There is often an implicit assumption that human behaviour and society are understood, and it is known how technology can be placed within it for a maximum effect, without properly ever examining it. We are still incredibly technocratic and top-down in how we go about introducing technology. We need to be much more bottom-up and start with community, society and individuals, address how and where technology fits within these respective facets and not to go finding a solution looking for a problem. Funding mechanisms and emphasis on market-driven policies fuels this in the western world. To have technology that is harmonious within human life, we need to start with understanding and examining our lives.

Therefore, more research is needed to expand understanding of how human behaviour connects with life and society and its fit with technology. To create and implement technology to work well with people in, for example, a remote northern community above the Arctic Circle, developers must first understand how such communities live and where technology can support rather than hinder their daily lives. There is a need for greater emphasis on coproduction of technology and more ethnographic work with potential users including a range of people and communities.

Contributions to this book have all highlighted the need to increase involvement from users in the design of mobile eHealth. Too often the needs of users are assumed without the existence of evidence-based research and stakeholder consultation with the users first.

Techniques outlined in Ruzic and Sanford's chapter enable a more user-centred design approach to designing the interface between the individual and the technology. It is often posited that technology has a mind of its own as it may or it may not behave exactly in the way it has been designed and programmed. Indeed, the development and introduction of the internet may be considered an example of this. One may question whether the developers of the internet ever could have imagined its widespread use and integration into daily life of persons across the globe. If the

technology does not perform as expected, then that's often believed to be a misunderstanding of the technology and its resulting interactions with individuals. It is at this interface that many of the chapters in this book are calling for the need to pause and examine. It is here where the technology, the apps, the games and the widgets have a potential to enhance or disrupt the individual's behaviour, and it is here where concentration of further research is needed.

Here, ethics and dilemmas meet and warrant space to identify procedures, standards and laws to ensure that the interaction is favourable and non-harmful to the individual and to society. The book covers these in Part VI – from Lynch and Fisk, Mantovani and Cristobek Bocos and Wiersinga. All these chapters highlight the contention in that space and offer solutions, but note that solutions are not easy to reach and that one size fits all may not always be the solution.

One of the key aspects to emerge in the eHealth and mHealth debate is innovation. Technology is creating completely novel ways of how society and individuals interact with health and wellbeing. These completely new structures and ways mean that existing structures are challenged, contested or disrupted. Quite often completely new systems are needed to be created for the technology to become useful.

In terms of regulation, Wiersinga (Chap. 13) reminds us that new apps can be seen under the same guidance as medical devices in some countries and in some contexts, therefore having to meet stringent guidelines in order for them to become used. However, they can also be seen very differently, even if they are doing the job of a medical device. Technologies can also bring together professionals. The sharing of expertise matched with sharing of patient records and history must be of benefit to the individual patient, for example. But, without proper understanding of what is needed from each professional and how they operate and work together, along with legal and ethical issues of sharing information, such systems are not likely to be used to their potential.

An ultimate goal of such technology is for the individual to truly understand his or her health from the eHealth and mHealth supporting systems. How such technology can enhance the user to become fully informed of their own health and be able to make changes in respect of this information is championed. However, the psychology of how individuals interpret such data and how they go about acting up on such data is not yet well known. It is still not possible to understand how such systems should be designed for positive behaviour to follow. Should a system simply provide passive information for the user to interpret (e.g. steps walked, calories ingested, heart bear rate, etc.), or should the system then advise the user (e.g. "you need to do more exercise today") and if so how? How should warnings be communicated? How should feedback look? Does it need to be normed at all, for example, for age, gender, culture or the individual? Could future systems even go one step further and stop the user altogether from conducting behaviours which could be perceived bad for their health?

We too often misunderstand that technology entwines with society, with communities and with groups. It is not an individual thing. Yet most of our research examines how technology impacts on individuals. Technology mediums change the nature of interactions between people. Martin-Khan and colleagues (Chap. 8) provide a description of the evolution of telehealth and note how health care systems

are progressing to an era where telehealth is becoming embedded within mainstream health services as part of regular care rather than an additional add-on service. There are examples such as telehealth where there is a need to examine how technology-based interactions work and are complementing, contrasting or replacing face-to-face human contact. Telehealth challenges society to stop viewing technology as something that patches a gap or responds to a problem in someone's life or in society and instead that it is part of ensuring efficiency and quality of care from the health system. Technology can work with existing structures of society and with people, but it cannot alone solve problems without understanding how the problem arises and what the problem is in the first place. More understanding of the problem would be useful. Naturally, mobile eHealth can aid this.

Technology continues to be treated as a separate entity and as a separate subject. Technology involves a sum of much more than engineering, computer programming and design. Instead, it is argued that technology should be considered from a multi-disciplinary vantage point that marries computer science (technology hardware and software) with humanities, social sciences and medicine (health promotion, behaviour change and improve quality of life (QoL)). Health and social sciences need to take on a greater role but, simultaneously, so should the arts and humanities. Ethical dimensions of technology must be positioned within comprehension of design. People do not live their lives in silos of science and art. Instead, people are immersed in a mixture and so, therefore, must our technologies.

The section on the immersive technological art project, Splash, presented in Chap. 5 by Paczynski et al., highlighted how creativity and art can improve body movements, improving health and well-being through immersive art. How eHealth games can improve health and well-being is demonstrated in this book in Chap. 7 by Marston et al. and in Chap. 9 by Holz et al. When examining how mobile eHealth can be used as an intervention to improve health and well-being, one must look beyond traditional behaviour change techniques such as the linear deficit. The simplicity of the model is appealing, as the mobile or eHealth intervention only needs to contain information and people will change their health behaviour for the better. Although it is widely used in behaviour change interventions (e.g. health and safety campaigns), it is largely now discredited, at least in its simplest form.

Can mobile eHealth provide a better self-awareness to enact behaviour change? The introduction of quantified self can help illuminate individual problems in health in a continuous way, something never possible before. Earlier interventions or support are possible, but only if how to use such data is understood by the user, who can make an informed decision. Users must be aware and able to understand what the data collected about them can mean and how they may leverage this personal information to best inform their behaviours. Part II addressing the quantified self by Sacramento and Wanick and De Mayer is an important piece which raises such questions.

14.2 Future of Mobile eHealth

The future of mobile eHealth and related technologies is fascinating and is evolving at a quick pace. Since the turn of the twenty-first century, society has witnessed many technological (both software and hardware) developments that have transformed the way societies live their lives. For many in the Generation X (Gen X) cohort who grew up in the age of digital games, playing PacMan, Super Mario and Sonic the Hedgehog on PCs and respective game consoles, it is difficult to believe that within less than a decade or so, communication and gaming technologies were about to change to facilitate a different notion of interaction (e.g. Nintendo Wii and DS), mobile and smartphones leading onto the mobile (health) apps.

Thus, in less than 20 years, younger generations such as the Millennials have borne witness to these technologies which for them are a part of everyday life and living. Such as this, social media has also played an important role in these young lives, whereby for many retrieving and sharing information such as photographs of everyday life, living and activities (e.g. going to a music gig, birth of a child or a holiday); communicating with friends and family through different means (e.g. sharing photographs, chatting in real time and 'updating' one's status); or 'adding' people to your friends list who one may have met on a holiday, at a music festival/gig, at the pub or through education.

A question to think about is what can society and younger generations expect from industry and research in the forthcoming decades? Will accuracy and reliability of mobile apps improve which in turn will facilitate health practitioners to diagnose quicker and in a more cost-effective manner? Will the design and development of technologies and their related software be designed with the notion of target users being involved from the beginning? Will researchers and practitioners extend their exploration to ascertain the barriers and enablers to technology use and ownership by our current ageing populations with the notion of preparing for our future ageing cohorts such as Gen X and the Millennials, who are in contrast very different to the Baby Boomer generation? Keeping in mind, for many Gen X and certainly Millennials, they have grown up with technology. Technology and its related attributes are like the television, the washing machine and the ironing board to the Baby Boomer generation. Indeed, the importance of access to information and communication technologies (ICT) for persons residing in rural communities has been equated to that of the introduction of the railroad for generations before (Ashton and Girard 2013).

For older adults, the exploration of technology use is increasing in popularity (Marston et al. 2016; Marston and Graner-Ray 2016) with technology now being geared towards improving the quality of life (QoL) of older adults, whether through applications for home support services (Marston et al. 2015), medication reminders, mirrors that display health data, medical implants or wearable technology (European Commission: Information Society and Media 2007). Research shows that technology can change the family situations of older people and is of utmost importance (Silverstein and Giarrusso 2010). As described by Marston et al. in Chap. 7, the

evolution of telehealth services has opened a door to improve accessibility to health care for many persons, including older adults. Technology use is becoming a routine practice for many older adults, with home computers being used to create a common interest among older and younger family members and improve family ties (Cotten et al. 2013; Lindsay et al. 2007).

We see through social media, personal experience and news bulletins that technology and social media can be fun and entertaining, and hopefully this notion will continue. Yet, it cannot be ignored that as a society, there is an ageing population, increasingly drawing on health and social care services and the need and want to maintain independent living, and, thus, is this where technology can really be a key player in society in the forthcoming decades?

Will it be the norm to have newly built housing, equipped as 'smart homes'? As a young person, couple or family moves into this new 'smart home', will it be ready for those living there to age in place, for example, door frames wide enough to allow a wheelchair to manoeuvre with ease? Will national and local governments, housing developers and contractors communicate and liaise with those who are involved in smart home technology and design, to ensure all designs prior to 'breaking ground' are suitable for those to 'age in place' successfully? Thinking about old age is not only important for younger generations, but as society continues to age and the current and future populations reach into their 100s, the notion of technology to support 'ageing in place' should and needs to be considered.

The future of technology and eHealth in the forthcoming decades will be interesting not only for society but also for researchers, industry and health practitioners. The possibility of using and deploying technology solutions to assist varying cohorts across the lifespan needs further and extensive exploration and study, in particular using mHealth apps which have the potential to assist users to self-manage and monitor their own health alongside their health practitioner.

Authors have noted that throughout their contributions in this book, there is more than just one facet that needs exploring. Functionality, usability and acceptability require further understanding and a coherent set of guidelines that all users can adhere by to be published. Theoretical and international studies should be explored to ascertain how different cultures and areas worldwide embrace new technological developments.

Further exploration is needed in relation to ethics and research ethics boards (REBs). Across academic institutions, public and private organizations and across geographies, REBs vary considerably. It is important to consider from a multidisciplinary and multi-institutional perspective how familiar REBs may or may not be with the associated research domain. Understanding and learning from bad experiences in respective studies are important to the academic community. Transparency in both successes and challenges with research should be possible.

This book has provided an insight into the current work within the domain of mobile eHealth. A common theme for all respective authors is that more work is needed. Great opportunities exist in the development and implementation of suitable technological solutions to assist all cohorts of society. Simultaneously, it must

be recognized that there is no one size fits all across the lifespan. Researchers and industry practitioners need to be mindful of the different levels of experience and ability of all involved from developers to end users. Understanding the needs and requirements of the respective target audience is crucial for designing and deploying technology. However, for mass take-up, patience and understanding what the specific technology or solution is going to bring to the person or cohort maybe more important than fancy functions and swish interfaces.

References

Ashton B, Girard R (2013) Reducing the digital divide in Manitoba: a proposed framework. J Rural Community Dev 8(2):62–78

Cotten SR, Anderson WA, McCullough BM (2013) Impact of internet use on loneliness and contact with others among older adults: cross-sectional analysis. J Med Internet Res 15:1–18

European Commission: Information Society and Media (2007) Ageing society i2010: independent living for the ageing society. European Communities, Luxembourg

Lindsay S, Smith S, Bellaby P (2007) The impact of ICT on family: views from an older generation. In: Family and communication technology workshop. Retrieved from https://www.northumbria.ac.uk/static/5007/2008pdf/fact_impactfamily.pdf

Marston HR, Graner-Ray S (2016) Older women on the game: understanding digital game perspetives from an ageing cohort. In: Nierling L, Dominguez Rue E (eds) Ageing and technology: perspectives from the social sciences. Transcript-Verlag, Bielefeld, pp 67–92

Marston HR, Woodbury A, Kroll M, Fink D, Eichberg S, Gschwind YJ, Delbaere K (2015) The design of a purpose built Exergame for fall prediction and prevention amongst older adults. Eur Rev Aging Phys Activity (EURAPA) 12:13. doi:10.1186/s11556-015-0157-4

Marston HR, Freeman S, Bishop AK, Beech CL (2016) Utilization of digital games for older adults aged 85+ years: a scoping review. Games Health J 5(3):157–174. doi:10.1089/g4h.2015.0087

Silverstein M, Giarrusso R (2010) Aging and family life: a decade review. J Marriage Fam 72(5):1039–1058. https://doi.org/10.1111/j.1741-3737.2010.00749.x

Charles Musselwhite is an associate professor, Centre for Innovative Ageing, at Swansea University, and heads-up the groups Environments and Ageing research strand. He is Operational Director of the Centre for Ageing and Dementia Research (CADR), an initiative to develop and enhance research, policy and practice for older people across Wales. He has a particular interest in ageing, travel and transport, addressing technological, environmental, health and sustainability contexts of transportation and built environment studies. Prior to joining CIA, his research addressing ageing and transport spans four interconnected areas including (1) attitudes to transport and travel; (2) older people, travel behaviour change and health and wellbeing; (3) giving up driving for later life; and (4) road user safety and ageing. Dr. Musselwhite has been involved in a variety of other built environment, mental health and shipping projects. Charles has advised the Parliamentary Advisory Council for Transport Safety on older people's transport issues. He is a member of the British Society of Gerontology. His research on older people and their travel and driving behaviour has involved several invited international and national presentations at conferences and invited presentations to the House of Commons and the House of Lords. He has appeared on BBC TV and UK and Swedish radio stations on the subject.

Shannon Freeman is an assistant professor in the School of Nursing at the University of Northern British Columbia, co-president of the British Columbia Psychogeriatric Association, current vice president of the International Association on Geriatrics and Gerontology Coalition of Student Organizations and an interRAI Canada researcher. Dr. Freeman's research interests focus on the health and wellbeing of vulnerable populations with current research projects in the areas of gerontechnology, mental health and wellbeing of older adults and First Nations Elders and long-term care. She is a director of the Prince George Hospice Society and also takes an active role in research examining hospice palliative and end-of-life care.

Hannah R. Marston is a research fellow, in the Health and Wellbeing Priority Research Area (http://healthwellbeing.kmi.open.ac.uk/) in the School of Health, Wellbeing and Social Care, at The Open University, UK. In March 2017, Dr. Marston organized the first digital health and wellbeing symposium as lead of the Digital Health and Wellbeing Special Interest Group in the Health and Wellbeing Priority Research Area. The event was attended by external academics from across the UK and comprised of several external speakers and a panel discussion. She is currently organizing the 2nd Digital Health and Wellbeing conference to be held between 1–3 May, 2018, at The Open University campus. Hannah has published over 20 journal papers and 5 book chapters and currently serves on two editorial boards. Previously, Dr. Marston has worked internationally undertaking fixed-term positions in Germany as a research scientist on the iStoppFalls EU project at the Institute of Movement and Sport Gerontology at the German Sport University Cologne and in Canada as post-doctoral fellow at the University of Waterloo. Hannah interests are multi-cross disciplinary and include digital games, gender, ageing, lifespan, gamification, technology use and health.