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# Mobile e-Health

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# Mobile e-Health

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# 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.

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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.

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**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

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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©

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|---|
| *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)

| |
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| *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

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|---|
| 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

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|---|
| 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

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|---|
| 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 touch-screen 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).