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INTRODUCTION TO m-HEALTH

> We have a seemingly insatiable desire to communicate, search, find, share, watch, listen, learn, experience, download and upload information. Year on year the demand grows exponentially.
>
> Peter Cochrane, Technology Futurologist.

1.1 INTRODUCTION

When the concept of mobile health (m-Health) was first introduced and defined in 2003, there was no indication a decade on that it would become the fourth ICT for healthcare pillar after telemedicine, telehealth, and e-Health. Since then, numerous papers and books have appeared in the literature on this topic, together with a multi-billion dollar healthcare delivery-related industry embracing m-Health as its main service. While m-Health is rapidly expanding in the commercial world and has effectively evolved into a separate applied scientific discipline, it is still "under the radar" in general and probably some way from being fully adopted by the medical world, although this gap is narrowing.

The introduction of smartphone technologies has played a major influential role in the evolution of m-Health, albeit in a focused way, particularly in well-being and health-monitoring applications. This role is both a blessing and a curse: the blessing is that technological breakthroughs in mobile and Internet communications are putting m-Health on the global radar, while the curse is the false notion among many people

m-Health: Fundamentals and Applications, First Edition. Robert S. H. Istepanian and Bryan Woodward.

that m-Health is merely another "App" (application). This book is an attempt to present the full picture.

Nowadays, if you type the word "m-Health" into a search engine, the result will be an astounding 100 million or more hits. The 2009 inaugural m-Health Summit, a partnership between the Foundation for the National Institutes of Health and the m-Health Alliance, attracted 800 people; this attendance increased to over 4000 participants from 56 countries at the Fifth Summit in 2013 (Slabodkin, 2013). This is the level of interest that m-Health has generated globally among healthcare providers, academia, and the telecommunications, biomedical, and pharmaceutical commercial sectors.

In this chapter, first we look back briefly at where it all started, then we consider the digital world and the impact it has had on the concept of m-Health. Finally we discuss the correlation between mobile communications and Internet technologies, their role in the future of m-Health, and consequently their social impact on future healthcare services; this is currently being termed "smart health" or "digital health."

We start by defining the various labels that constitute the "Information and Communication Technology (ICT) for Health" domains and how they have been adopted in relation to m-Health, sometimes incorrectly. The notion of m-Health (which we define later) implies an underlying digital ingredient, and the ubiquity of the digital world is exploited in all healthcare applications. The main components that constitute the "building blocks" of the m-Health concept, that is, wireless medical sensors, mobile communications, network connectivity, and the Internet, are themselves invariably digital systems. This combination comprises a powerful trilogy that has spawned an impressive number of applications, but in the years ahead, now with the availability of 4G connectivity, cloud services, Internet of Things (IoT) and Web 2.0, and doubtless future technologies previously undreamed of, these advances will transform the world of medicine and healthcare in a truly spectacular way.

1.2 THE CONCEPT OF m-HEALTH: THE BEGINNINGS

The parable of inventing the wheels on travel luggage is perhaps the best way to describe the beginnings of m-Health. On August 16, 2012, the *USA Today Travel* newspaper published a special report in their travel section (Clark, 2012) entitled "The innovation that revolutionized the traveler's world had humble beginnings," which highlighted how a simple idea, the invention of travel luggage with wheels, can cause millions of people to say: "why didn't I think of that?" The originator of the idea was Robert Plath, a Northwest Airlines pilot who noticed, while queuing behind passengers at an airport security check point in 1987, how many of them were struggling to detach their bags from bulky metal luggage trolleys. Nowadays, almost every sizeable travel bag and case has in-built wheels, which has changed everyone's travel experience for the better. But no one today has heard of Bob Plath, the originator of an innovation used daily by millions of travelers!

The relevance of this story is that it has a parallel with the inception of m-Health. Few know that the Eureka moment on m-Health came in 1996 when the lead author of

this book was reading a magazine article at San Francisco Airport about using the then new cellular phones to remind elderly patients to take their medications. From that moment, the concept of using a mobile phone for other medical applications emerged, followed by the publication of the first paper on the modeling of a wireless telemedicine system (Istepanian, 1998). Around 1999–2000, several landmark papers mentioned the principle behind m-Health and presented the basic concept but did not define it clearly as "m-Health" (Istepanian, 1999, 2000; Istepanian and Laxminarayan, 2000).

What is m-Health? Literally, it means "mobile health," which in the context of this book means the use, for health-related applications, of sensors, mobile devices such as "smartphones," tablets, and laptops, and the huge infrastructure of communications networks already in place. New language abounds in m-Health, not least confusing expressions such as "mobile health eco-system," which defines the scope of mobile health in terms of patient, clinician, healthcare provider, service provider, mobile device, and applications (GSMA, 2011).

To the best of our knowledge, the first citation of the word "m-Health" was mentioned in 2003 (Istepanian and Lacal, 2003), followed by the first definition of the concept as *mobile computing, medical sensor and communications technologies for healthcare* (Istepanian et al., 2004). These three basic building blocks are now widely adopted globally for m-Health as one of the main domains of ICT for health. It is also well known that there were no "m-Health" or "mobile health" terms mentioned anywhere prior to these seminal papers. These facts on the beginning of the concept and its original definition have never been documented *prima facie*.

In 2011, the World Health Organization (WHO) defined m-Health as covering "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices" (WHO, 2011). This and other confusing definitions have contributed to the status quo and to ambiguity over the concept's original definition.

Why is m-Health important? One reason is to reverse the traditional event-driven situation in which a patient consults a doctor only when he or she is ill. Instead, recent advances in m-Health allow the patient to be continuously monitored (which may be resisted by some people and is possibly controversial) by a smart sensor network to detect any indication of illness before it occurs. This "well-being" monitoring model can prevent emergencies and empowers patients to be proactive. It therefore allows the realization of a patient-led (or patient-centric) healthcare model rather than a doctor-led model, something that governments are keen to support as a potential means of reducing health expenditure. Some 6 billion mobile phone users globally who are concerned about their health can now exploit the unprecedented evolution of m-Health, with phones that are increasingly equipped with touch screens and Apps that control sensors, Global Positioning System (GPS), camera, and many other features, linked globally by a variety of communications networks. The latest smartphones are even equipped with embedded heart rate and well-being sensors that can calculate real-time heart rates and exercise levels with a touch of the screen. This does not imply that m-Health is merely a smartphone health delivery system as is widely recognized. We will discuss this issue further throughout the book.

There is another reason why m-Health is important; it is that advances in its three main building blocks have enabled the parallel development of innovative mobile healthcare applications and services. To cite an example of its importance, a search of "m-Health" on YouTube results in more than 10 million hits. Another example where the concept entered a major yet controversial leap in its evolutionary process was the introduction of the first smartphone (the iPhone) in 2007; nowadays, tens of thousands of medical Apps are downloaded and used for different medical, well-being, and healthcare delivery applications worldwide on Apple Store or Google Play. This relates to a further reason, and perhaps the most important one, which is the market potential of m-Health, particularly for developing new healthcare delivery models and services that can be more efficient and cost-effective.

In a study by the IMS Institute of Health Informatics, it was estimated that by October 2013 there were 43,689 Apps under the categories of "healthcare and fitness" or "medical," out of which only 23,682 were considered genuine healthcare categories (IMS online).

Table 1.1 shows the results of a survey indicating an increasing trend by physicians and healthcare providers to perform different healthcare activities on mobile devices between 2010 and 2014 (PwC, 2014). Although these results relate to the United States and other high-income countries, similar trends are becoming increasingly evident in many global healthcare service delivery settings.

This evolution would not have been feasible without rapid advances in wireless communications and network technologies from about 2000, when progression from the Global System for Mobile Communications, or Group Spécial Mobile (GSM), to the General Packet Radio Service (GPRS) made it possible to send packet data over networks linked to the Internet. This, for example, enabled for the first time medical "vital signs" such as electrocardiogram (ECG), blood pressure, body temperature, and photoplethysmography (PPG) signals to be sent to a remote server using cellular

TABLE 1.1 Survey of the Increased Trend of Healthcare Activities Performed by Physicians on Mobile Devices 2010–2014

Healthcare Activities Performed by Physicians on Mobile Devices	% in 2010	% in 2014
Access Electronic Health Records (EHR)	12	45
Prescribe medications	14	41
Review images	7	32
Communicate with patients	21	31
Receive data from medical devices	11	20
Initiate and track a referral	6	17
Conduct clinical consultation from different location than the patient's	5	12
Monitor patients who are hospitalized	N/A	17
Receive data from a mobile App	N/A	14
Patient tracks data		

Adapted from PwC HRI (2014).

networks (Istepanian, 1998). This synthesis of mobility and healthcare that forms the basis of m-Health has been quickly adopted by telecommunications, and mobile and medical devices industries, reflecting the huge potential markets envisaged; this has already been realized, albeit with mostly consumer-driven rather that clinically driven outcomes. For example, one study estimated the opportunities in the global mobile healthcare market to be worth between $50 and $60 billions (McKinsey, 2014). In 2014, there were more than 60 industry-sponsored and academic conferences and events relating to m-Health (m-Health Insight, 2014). These activities reflect the global interest and commercial opportunities in m-Health.

The concept is still evolving in its second decade, and as sensing, computing, and networking technologies become ever more refined, advanced, and accessible, there will be a growing demand for all that m-Health has to offer in the future.

1.3 TAXONOMY OF TELEMEDICINE, TELEHEALTH, e-HEALTH, AND m-HEALTH

Before we present details of the m-Health domain, it is imperative to clarify some of the different terminologies used in the ICT for health domains. The increasing number of terms has become so confusing, to experts as well as to lay people, that attempts to classify them have been made, including developing different "taxonomies" (Bashshur et al., 2011). These aim to establish a clear classification of how telemedicine fits with other related domains, notably telehealth, e-Health, and m-Health. These labels have led to the spawning of several international journals since the early 1990s, notably *Telemedicine and e-Health Journal* and *Journal of Telemedicine and Telehealth*, and numerous books, reports, and literature reviews (Bashshur et al., 1997; Yang and Hui, 2008; Olla and Tan, 2009; Currell et al., 2010).

A practical reason for this classification is to attempt to shed light on the true effect of these domains in terms of the cost, quality of service and access to care, or for treatment or monitoring. Further considerations are the place for medical research, health policy, and reimbursement of network charges. For many years it has been asserted that the main benefit of remote medical access is to save time and money, especially for patients, who then do not need to travel from home to a hospital or clinic for a consultation with a doctor. This has still to be verified but it is a worthy goal; for example, if new m-Health procedures could save just 1% of the UK's National Health Service budget, this would amount to more than $1.5 billion annually.

The presumed advantage of establishing the taxonomy—as with flora and fauna—is to bring order out of confusion, to try to fit the various domains and components into a pattern. By its nature, this is not an exact science and numerous iterations may be expected before some definitive blueprint is widely accepted.

In has been proposed that ICT for health domains, or classes, may be thought of as consisting of four key "domains of care" (Bashshur et al., 2011): telemedicine, telehealth, e-Health, and m-Health, as illustrated in Fig. 1.1. The premise is that these terms are not interchangeable because they represent different concepts and related activities, and this becomes evident if we consider their origins.

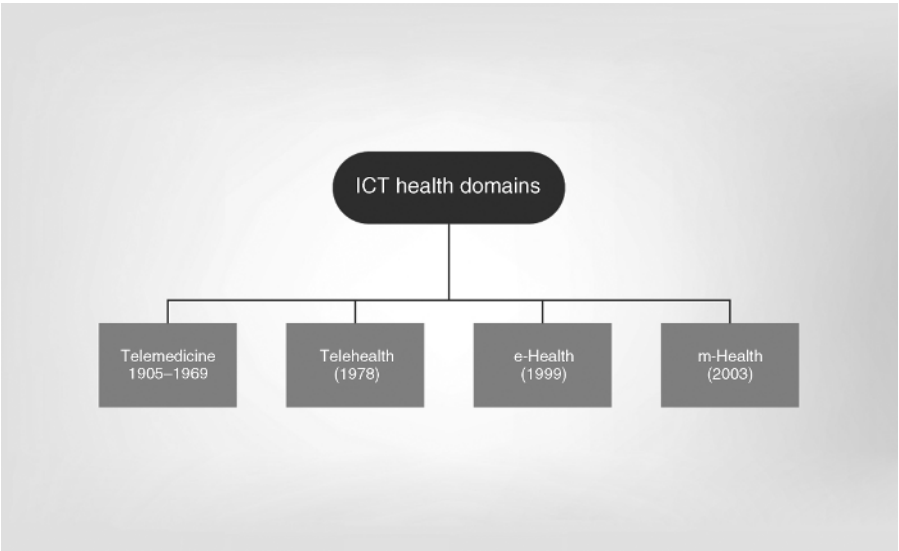

FIG. 1.1 Key domains of ICT for health. (Adapted from Bashshur et al. (2011).)

Telemedicine has been in use since about 1969 (Currell et al., 2010). Since then, telemedicine has been extensively adopted as an umbrella term, and it is appropriate to quote some of key definitions as a starting point: "telemedicine involves the use of modern information technology, especially two-way-interactive audio/visual telecommunications, computers, and telemetry, to deliver health services to patients and to facilitate information exchange between primary care physicians and specialists at some distances from each other" (Bashshur et al., 1997). Another broad definition defines telemedicine as "the use of telecommunications for medical diagnosis and patient care. It involves the use of telecommunications technology as a medium for the provision of medical services to sites that are at a distance from the provider. The concept encompasses everything from the use of standard telephone services through high speed, wide bandwidth transmission of digitized signals in conjunction with computers, fiber optics, satellites and other sophisticated peripheral equipment and software" (Scannell et al., 1995). More concisely, telemedicine may also be defined as the use of communications to exchange medical diagnostic and therapeutic information, usually between a doctor and a patient who are in different places (Woodward et al., 2001).

The simplest application of telemedicine is, of course, a telephone call or text message between a doctor and a patient. Far from trivializing the subject, this is an example of the literal meaning of telemedicine: *tele*, meaning *far* or *distant*, and *medicine*, meaning *to treat* or *to cure*. A recent review outlined the empirical evidence of telemedicine interventions for diabetes as an example of the effectiveness of telemedicine in some important clinical specialisms and chronic diseases (Bashshur, 2013; Bashshur et al., 2015).

Telehealth came along in 1978 to mean a broadening of the scope of telemedicine to include public health, health education, health services, environmental and industrial health, among others. In terms of taxonomy, telehealth may be seen as a separate domain but there is no hard and fast rule about this. In general, telehealth (sometimes assumed to come under the telemedicine umbrella) deals with remote monitoring by health professionals of a patient's physiological data for diagnosis and disease management. There is also the term *telecare*, which is generally defined as the use of different sensors and alarms to assist people to live independently. This again leads confusingly to the erroneous notion of m-Health as being another telehealth application that uses wireless technologies for remote monitoring using mobile phones.

e-Health has an origin that is still debatable, but there is a general consensus that it started in about 1999–2000 with the start of "dot com bubble." There is now a profusion of words with the "e-" prefix, such as e-book, e-ticket, e-business, e-commerce, and e-government. It seems, then as now, that anyone can make up such a word! In 2005, a study on this topic revealed 51 definitions of "what is e-Health?" (Hans et al., 2005). There is no doubt that more of these definitions have been introduced since then.

e-Health was defined by the WHO as "the cost-effective and secure use of ICT in support of health and health-related fields, including health-care services, health surveillance, health literature, and health education, knowledge and research." The key common ground for e-Health is the use of technology, electronic processing, and communication networks for different healthcare services.

A proposal for the components in the e-Health domain is shown in Fig. 1.2; here, e-Health comprises electronic health records, health information, clinical decision

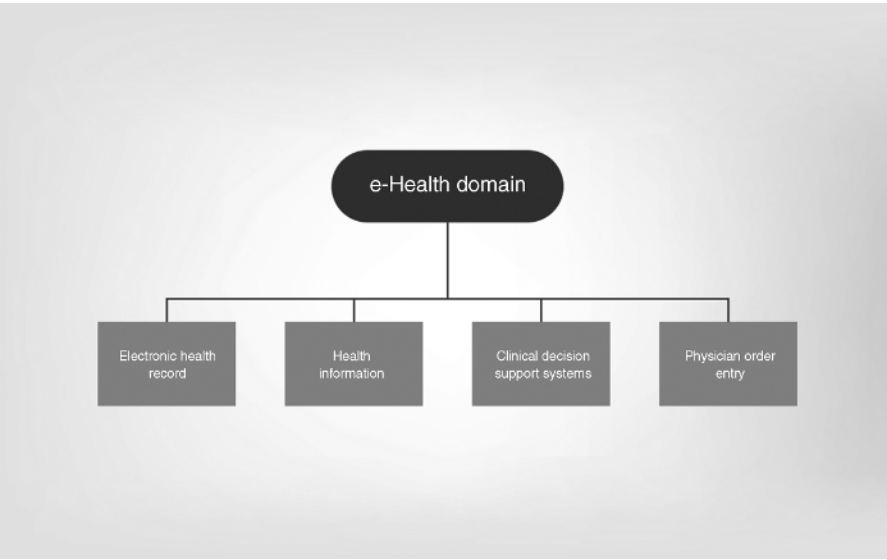

FIG. 1.2 Key domains of e-Health. (Adapted from Bashshur et al. (2011).)

support systems, and physician order entry (Bashshur et al. 2011). This concept has also led some global institutions to categorize m-Health as an offshoot of e-Health with an added wireless element.

The WHO, in their Global Observatory for e-Health service report, asserted that there is so far no standardized definition of m-Health, citing it as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, PDAs, and other wireless devices" (WHO, 2011). However, some of the terminologies and interpretation used in this definition (e.g., the now obsolete PDA) are strongly debatable and add to the confusion surrounding the nature of the m-Health concept. There is also the obvious view that the inclusion of m-Health as a subdomain of e-Health reflects the current paradox of the differentiation between the two concepts.

m-Health, as mentioned earlier, was first coined and defined in 2003 as *mobile computing, medical sensor and communications technologies for healthcare* (Istepanian and Lacal, 2003; Istepanian et al., 2004). This basic definition is still valid today, as it simply represents the essence of what the m-Health concept is all about. It also reflects the adoption of this domain as a triumph of digital ubiquity and technical evolution that we witness today, from technologies such as smartphones, 4G cellular networks and beyond, cloud computing, smart wearable medical sensors linked with the IoT, and machine-to-machine (M2M) communications. Telecommunication industries were the first to embrace mobile health as part of their future business and revenue models, with Vodafone being the earliest in 2006. As already mentioned, this domain is defined as much in terms of associated technology as with health concepts (Istepanian et al., 2006).

Several derivative definitions of m-Health have been cited that erroneously categorize mobile health as part of e-Health, telehealth, or telemedicine (Free et al., 2013; Fiordelli, 2013; Kwan et al., 2013). Observers argue that it does not matter how you define m-Health. However, such arbitrary definitions fuel the confusion and sometimes misunderstanding to the lay reader on the essence of the m-Health concept. It widens the gap between understanding the science of m-Health as opposed to viewing it as the provision for healthcare services and information using smartphones, as it is widely understood.

The basic concept of m-Health is illustrated in Fig. 1.3. This concept has evolved into a major technological and applied scientific domain with global commercial interest that embraces advances in the healthcare, computing, and telecommunications sectors. It brings together academic researchers, medical specialists, and business experts worldwide to achieve innovative solutions in healthcare delivery using advances in these technologies. Further developments in the near future will benefit from ultrafast mobile broadband connectivity with new Internet architectures, enabling much wider global access to healthcare services on demand.

These technological advances are well known to be spiraling almost out of control and are therefore inevitably way ahead of any changes adopted by the medical profession, even in the developed world. While something may be achieved technically, it is another matter for doctors to introduce a new treatment or mode of working or clinical procedure into everyday use. This is a challenge for the future.

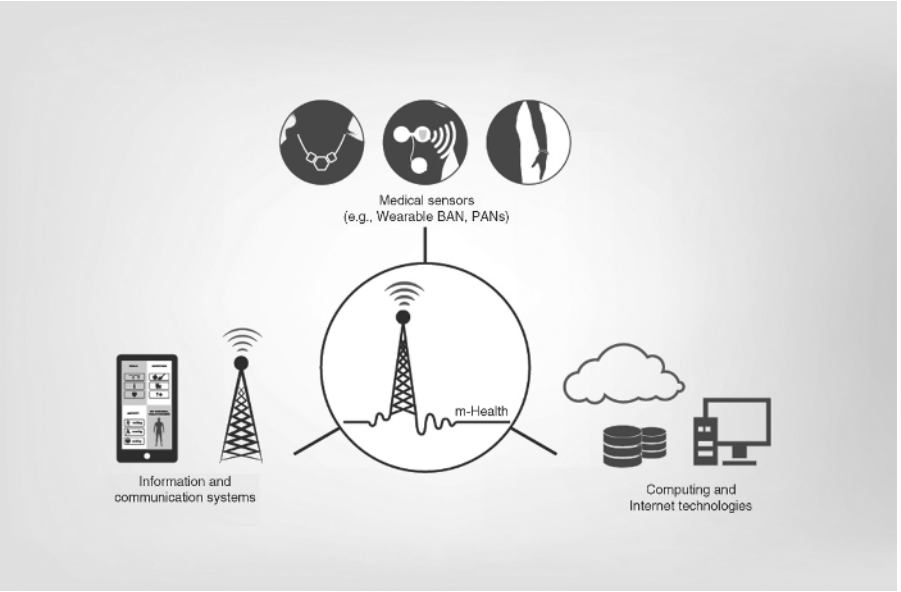

FIG. 1.3 Basic building blocks of m-Health. (Adapted from Istepanian et al. (2004).)

1.4 m-HEALTH AND DIGITAL UBIQUITY

In simple terms, m-Health exemplifies our digital world from the healthcare perspective, so it is worth taking a brief sojourn into this world to consider how it might affect us when truly personalized health systems are available to everyone. Some have found alternative terms for m-Health, for example, "connected health" or "digital health," to reflect the fact that most of what is happening in the new digital communications era is based on one form or another of mobile devices and terminals (Williams, 2013).

The "digital ubiquity" terminology is of vital importance in any aspect of science or engineering to do with "signals," or how we represent information. For the lay reader, an analog signal is continuous, while a digital signal represents discrete samples of the analog original. Hundreds of textbooks describe them and how one can be converted into the other. Although we will not repeat the process, it is at the heart of many practical engineering applications, including biomedical and other related disciplines and applications that we will consider in this book. In practice, "digital" represents progress, as manifested by the demise of now obsolete analog television sets in favor of digital sets.

Now that we are so dependent on mobile devices—smartphones, smart tablets, Kindles, tablets, laptops, and the like—we have unconsciously adopted a lexicon of technical language without necessarily understanding its meaning. We send e-mails and texts, we use Facebook, we tweet using Twitter, and Skype (and use ghastly new verbs like these!), and feel completely at ease with this new jargon without

appreciating the enormous technological achievements that have made it all possible. We have entered the "digital world."

We will probably adapt well to the digital world in the m-Health context, as we have done so in the business world, because this digital ubiquity has led to what has been called "constant connectivity" or "continual digital stimulation" (Topol, 2012). It is no exaggeration that many people, particularly young people, seem to be almost surgically attached to their smartphones. They cannot go 5 minutes without being in contact with someone else out there in the ether or checking their e-mails or looking up something on the Internet. People walk along the street tapping out texts or talking to themselves (or so it appears), often ignoring their friends who are there in the flesh. It is now a common experience to walk into a university dining hall and see groups of students all in contact with someone else who is not present, while surrounded by others. It is a form of social exclusion: someone who is in touch electronically gets your attention, while someone who is there in your presence gets ignored. It is therefore highly probable that m-Health will become the key enabler and means of communications between healthcare providers and future generations of digitally aware patients.

While this is a new phenomenon, the power of the telephone has been exploited for decades. One of the authors (B.W.), when working as a research associate at Guy's Hospital Medical School, London in the early 1970s, found that it was often difficult to get an appointment with the Head of the Anatomy Department, who had a zealously protective secretary. The way to get to talk to him was simply to phone him; without realizing it, he somehow felt compelled to answer the ringing menace on his desk!

As Topol puts it, the digital revolution has introduced a new syndrome of "constant connectivity" with a tsunami of digital data—always checking e-mails, making phone calls, sending texts, taking photographs and sending them instantly, to such an extent that this form of anti-social behavior, to any non-addict, has now become "normal." While it is not entirely acceptable, it is difficult to get young people to break the habit, even temporarily, for example, during a meeting, dinner in a restaurant, or even a theatre performance.

What drives us to this kind of behavior? Many suggestions have been put forward to explain this always-on lifestyle, such as a "digitally induced attention deficit disorder" (Richtel, 2010), which induces smartphone devotees, the new "digerati" (digitally literate), to seek "information without knowledge" and subject themselves to "data diarrhœa" and a "deluge of digital drivel" (Topol, 2012). The "Google effect" and the addiction to screen watching is all too self-evident in many people; it is the preserve of a new species called *Homo distractus* and if we are guilty of joining this club, we may be said to be "outsourcing our brains to the cloud" (Keller, 2011).

So, many of us—again mainly young people and the digital savvy generation—are effectively preconditioned to take on the technology of m-Health in the near future, as evidenced by the increased use of smartphones, social networking, and downloading Apps. The key challenge for m-Health is to convert this digital behavior to realize positive and better health outcomes. This is one of the main research targets in the development process of new mobile health systems and their clinical impact and benefit issues.

With a smartphone, we are half way there. Only the body sensors need to be added to the mix. Some of these medical sensors, such as those for heart rate monitoring and for exercise and fitness applications, are already embedded in some of the newer smartphone models on the market. One of the many concerns with social networking in the healthcare domain is that people with medical problems, real or imagined, are seeking diagnoses and potential cures from the Internet rather than from their doctor. There are also thousands of Apps that purport to monitor and diagnose a vast number of health parameters. It is a worrying trend because it is one thing to obtain the data but quite another to make sense of it. The machine cannot make a reliable diagnosis; that requires the intervention of a doctor, whom many people are reluctant to consult unless they are actually feeling unwell. Ethical and privacy issues, along with concerns of using downloaded Apps, will inevitably be subject to scrutiny by the medical world in the coming years.

It is estimated that the use of smartphone technology can create more than 5 billion points of contact between consumers, healthcare workers, health system administrators, and firms in supply chains for health commodities (World Bank, 2012). Ironically, while smartphones may be seen as a potential cure-all, with reservations, there has been concern for many years that their over-use may be a health problem in itself, notably brain tissue heating, although most studies have yielded negative or inconclusive results (Patrick et al., 2008). This issue has been largely underestimated, especially with the massive increase and sustainable use of mobile phones globally. These issues were studied extensively with yet unclear long-term outcomes on human health (WHO, 2006, 2013) and warrant further research within the development process of future mobile health systems.

With major technological advances in smartphones and cellular network structures, commensurate with wider frequency spectra and operational modalities of the forthcoming 5G-based smartphones, tablets, and the IoT connecting billions of everyday devices worldwide, this issue needs careful revisiting. From the healthcare perspective, these and other factors, such as cybersecurity, privacy, and ethical concerns, constitute the "dark side" of m-Health that warrants further attention and research.

The current debate is also raging on the privacy and security of so-called "big medical data" obtained from patients, because the huge amount of data that can be stored is virtually unlimited. In 1969, NASA put Armstrong and Aldrin on the moon using a computer with the computing power and memory capacity of a pocket calculator. Their systems were triplicated, so that if one of them failed they still had two backups, and if a second one failed they had a final backup. Think how much easier the moon landing would have been with a modern tablet or a smartphone, with their sophisticated software and huge memories!

The volume of the "big health data" and what to do with it is another consequence of this digital ubiquity. Nowadays, thousands of servers are out there, each with a vast memory. The label that has been adopted—"cloud"—reflects the impression of some immense computer but is arguably an understatement given the galactic scale of its memory. The amount of memory available in the 1980s, when the first laptops came on the market, was stated in kilobytes (1000 bytes, or 1000×8-bit words) and later in

megabytes (a million bytes); to put this in context, a digital photographic image needs typically 500 kB to 1.5 MB of memory so an early laptop could not store even one digital photograph. Nowadays, memory is stated in gigabytes (1000 MB), terabytes (1000 GB), petabytes (1000 terabytes), or even exabytes (1000 PB). These figures are beyond the normal human scale of appreciation. Making sense of this, if a photograph uses 1 MB, then an exabyte of memory could store a trillion photographs, that is, a million million. A new scientific area of "big mobile health data" is now born out of these developments.

The deluge of digital information from a "sea of sensors," including embedded sensors in smartphones, tablets, laptops, and other gadgets allows us to sense every parameter imaginable. The trend in the next decade is likely to be an exponential increase of data from these devices (The Economist Group, 2010). In the context of this book we have the capability to digitize almost anything related to biology and physiology, and although there is huge interest world-wide in doing this, with resources and effort from researchers and from industry, the medical profession remains—perhaps not without reason—cautious to some extent to such change. Medical ethics and privacy-related issues will be a major subject in the near future once these medical sensing and communications advances become more widely accessible and applicable. Technologists can show doctors what is possible, but for doctors to accept their suggestions is still a distant objective. Inevitably, and regardless of these discussions, it will take some time, perhaps a generation, before we have a truly "patient-led" or "patient-centered" society, as decreed by some Western governments, which are always striving, usually controversially, to increase "efficiency."

1.5 THE PARADIGM SHIFT OF MOBILE CONNECTIVITY AND m-HEALTH SERVICES

Figure 1.4 shows some of the key technological advances between the advent of the mobile phone in 1973 and the evolution of m-Health since 2003. We have come a long way in terms of technological progress from the field telephone, as used by the military in the early years of the twentieth century, but it was still a mobile system, albeit a hefty box encumbered with wires. More than half a century later, there were portable phones the size of a toaster, then in 1971 came what must have been a real breakthrough with the introduction of the Radiotelephone Chopper Bicycle, which was demonstrated at the Ideal Home Exhibition in London. In 1973, the first mobile phone call was made from a truly handheld device, as seen in one of the James Bond films when our hero used a phone the size of a house brick, now long since consigned to obsolescence. In the era up until about the 1990s, these budding mobile phone technologies are generally looked upon as the first generation (1G), although the term was not widely used at the time.

From about 1990, the first "normal-sized" lightweight mobile phones came on the market and in 1992 the first text was sent using the newly introduced short message service (SMS). There was little inkling then that "texting" (to use a new verb in the

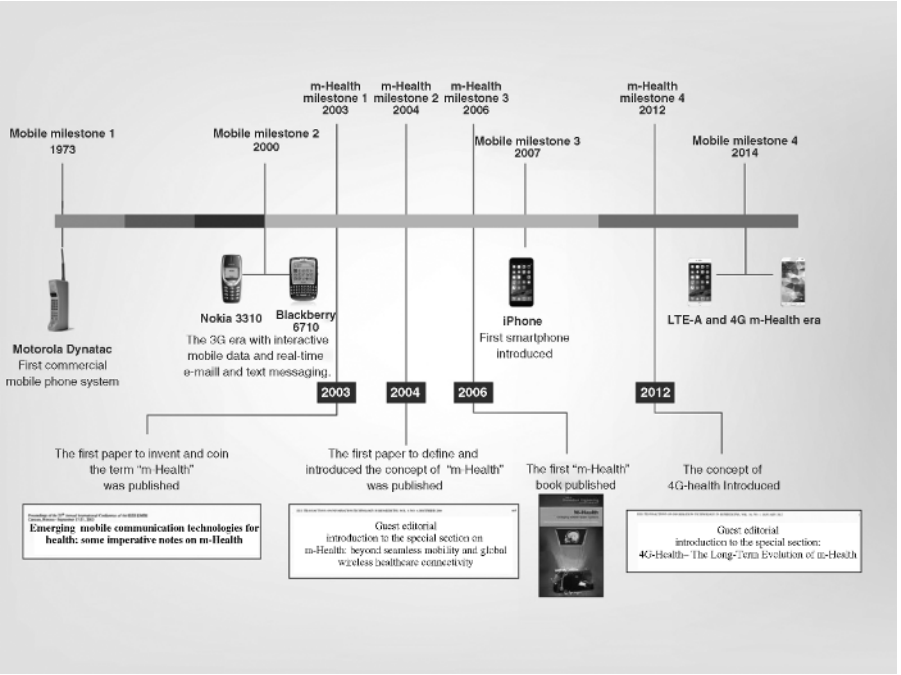

FIG. 1.4 A historical perspective of the evolution of mobile phones and m-Health.

English lexicon) would be so incredibly popular, probably superseding voice calls by an order of magnitude because of its cost-effectiveness. This second generation (2G) had limitations in terms of both bit rates (9.6 kbps) and operational coverage, which was much lower than for the Plain Old Telephone Service (POTS) of fixed lines. This provided limited capability for real-time data transmission but with a comparatively narrow spectrum available for medical applications.

A decade later, by about 2000, people had a taste for global communications and wanted more than a simple phone that they could carry around: They wanted a device of the same size that could do a lot more, such as take photographs and take on the role of a small computer. We were now into the third generation (3G) era of the now defunct PDA and the pre-smartphone era; in 2003, the Blackberry was born, then in 2007 Steve Jobs introduced the iPhone, heralding the beginning of the smartphone era that has had a profound effect on m-Health. A further milestone came in 2008 when Google brought in their Android software, which has since become a standard software feature on their smartphones and tablets.

In general, two major achievements have affected the evolution of m-Health since the early 2000s. The first was the launch of 3G, which brought a further advancement of cellular networks and data services. It allowed for the first time simultaneous voice, data, multimedia, wireless messaging, and mobile computing services, with improved quality of services for most of the first m-Health applications, for example, vital sign monitoring and real-time diagnostic applications. The concept of including high-

speed data and other services integrated with voice transmission emerged as one of the main innovations in future telecommunications systems, especially for patient-centered healthcare.

The second achievement was the introduction of the iPhone in 2007. This ushered a new yet controversial era for m-Health in which smart healthcare applications were developed in their thousands and could be downloaded by patients with a touch of the screen. This phenomenon moved m-Health from the mere research base to the wider world and made it the major mobile health application industry that we see today.

We are now, since 2012, in era of the fourth generation (4G), which has the capability of five times the data rate of 3G, with "theoretical" download rates of around 20 Mbps and upload rate of 22 Mbps (in practical and usability terms, the smartphone users have much lower Mbps download and upload rates than these). As of today, most 4G licenses from telecom operators are being rolled out globally, with higher speeds that will have a major impact on the mobile business and potentially on various mobile phone-centric m-Health services. A major advantage of using 4G is its ubiquity and personalization, with Internet access at the core of its connectivity and related services. It is expected that post-2020, the fifth generation (5G) will be launched, with smart wireless capabilities and data rates approaching the gigabyte per second range. These will open unprecedented opportunities for m-Health. Details of these technologies will be explained in Chapter 4.

This connectivity paradigm will have a major impact on future m-Health services and applications, especially for developing countries. This is highly significant for m-Health because it supports mobility, for both patients and doctors, and also allows recent developments in cloud computing and storage to be integrated with m-Health services, thereby obviating the need to store patient data on individual devices or servers and thus ushering the new era of "Big m-Health Data."

New cellular technologies from 4G, 5G, and beyond will also support the use of M2M connectivity and IoT paradigms as transformative communication protocols that will have a profound impact on future mobile health systems. At present, the only roadblock in this context is the lack of interoperability of the "machines"; these are sensors, body area networks, handheld devices (used as "gateways" between patients and the outside world), computers, their connections, and so on. For health monitoring, handheld devices, such as smartphones or tablets, will probably become redundant because future smart body area networks will be able to transmit directly to more conventional networks, as used for telecommunications. The urgent need for interoperability is probably the biggest challenge to manufacturers of these systems, who have to collaborate, make compromises, and therefore evolve business models that are beneficial to all, including the manufacturers themselves. The closest parallel scenario today is in advances in the homes automation sector, in which home security applications and utilities monitoring can be controlled remotely via smartphone connectivity.

Many of today's smart mobile phones, even the latest and greatest, will eventually become outdated, so it is pointless to promote particular brands. It will be interesting to reflect in, say, 10 years after their launch, how many of them have stood the test of time. Will the Apple iPhone 6, Samsung Galaxy S6, Motorola MotoX, and so on still

be around? As we read these pages, in few years from now possibly all these models will be obsolete. It is fair to predict that they will be superseded by more appealing versions with ever greater numbers of Apps, but it is likely that these gadgets will have inbuilt intelligent sensors that can be individually calibrated. The Apps themselves would not need to be hosted on individual phones because they would be sited in a "cloud" and downloaded when needed (Davis, 2013).

Perhaps "the need for speed" sums up the current 4G systems as well as any phrase, and in the m-Health context its use by the London Air Ambulance is a good example (Phelan, 2013). The major advantages of 4G here are the added speed of carrying out navigation to pinpoint the site where an accident has occurred, or where a patient is waiting, and the capability of transmitting high-resolution video images to a trauma specialist in a hospital.

Present and future technologies, from 4G to 5G and beyond, will support the development of effective medical care delivery well into the twenty-first century. The new wireless technologies will allow both doctors and patients to roam freely, while maintaining access to critical medical information (Istepanian and Zhang, 2012). It was predicted more than a decade ago that increasing data traffic and demands from different medical applications will be compatible with the data rates of 4G systems for true mobile applications. However, it is the organization and bureaucracy that will be slow to catch up and the following oft-quoted "equation" is worthy of mention (Istepanian and Lacal, 2003):

$$\text{Current organization} + \text{new technology} = \text{expensive current organization}$$

Hence, the expectations are for new generations of mobile technologies to be acceptable for challenges that include the following:

- *Aging Society:* There are increasing numbers of older adults with concomitant health problems and fewer young people, so that to sustain the economy, those older people will have to be persuaded to continue working longer. To be able to do this, a greater emphasis on the health of the elderly will mean an increase in demand for healthcare. At the moment, an obstacle to the implementation of m-Health is that commercial organizations do not regard the aging health economy as large enough to invest time and research in. We are probably at the cusp of a big change, because the growing demand for healthcare services and the reduced supply of service providers and caregivers will mean that m-Health suddenly acquires a heightened importance.
- *Fragmentation:* There is a fragmentation of care caused by the need to push down costs while still keeping abreast of rapid technological and medical advances. Such cooperation in healthcare will probably be achieved more by "patient power" than by government directives.
- *Expectation:* There is increased patient expectation because of easier access to information, which will mean that the preeminence of doctors will be challenged. Lifestyle changes will mean that affluent patients will tend to demand consultation and treatment at any time and wherever they are, although patients

at the lower end of the socioeconomic scale may have to settle for lower expectations.

- *Personalization:* Increased complexity of assessment, diagnosis, investigations, and treatment will mean a knowledge explosion and m-Health may serve a useful function of rapid dissemination of the skills and knowledge, especially in the genomic age. The increasing interdisciplinary area of personalized health will become a fundamental part of what future m-Health systems will look like and how they will function, as will be shown in later chapters.
- *Data and Security:* The availability of health-related data is particularly important and crucial for the development process of future m-Health systems. There is increasing influx of health-related data generated by smartphone users globally. This vast amount of data will require robust security and privacy measures and processing mechanisms that need to tackle the increasing worries and potential threats of when and where these data can be accessed and used, how these can be accessed by clinicians and healthcare providers, and so on.

1.6 IMPACT OF m-HEALTH ON CULTURAL, COMMERCIAL, AND OPERATIONAL CHANGES

A nation's health service is fashioned by its economy, demography, culture, and medical tradition, among other factors. This identity poses a challenge to m-Health, which can improve this service. In addition, there is the problem of "component management," which derives from the situation that the providers and payers of healthcare view health challenges only through the specific window of care for which they are responsible.

One of the main incentives to progress in healthcare is reimbursement and revenue models, which is basic to the cost of healthcare. Thus, telecommunications and Internet service provider companies are increasingly forced to organize their packages into reimbursable models. In the current economic climate, this issue is paramount for the future use of m-Health services.

Any task that falls outside these packages tends to be overlooked or receives low priority. From the mobile health perspective, component management systems serve patients poorly. The current healthcare service emphasis is on treatment rather than prevention, and there is a lack of incentive for providers to treat the entire disease process, which leads to an uncoordinated delivery system. However, there is a new wave of change advocated by mobile health providers to shift symptomatic care models to preventative care models, and future mobile health systems can be the enablers.

Some other key factors that may accelerate the diffusion of m-Health with social and medical impact are as follows:

- From a management perspective, planning for future implementation of m-Health services needs to favor mobile solutions to replace the old fixed computer-based Internet connectivity services.

- From an economic perspective, m-Health costs and savings need to appear on the same account to identify any benefits.
- From a government perspective, there is a need to fund promising m-Health initiatives that may be integrated into the healthcare system, and to make comprehensive assessments of m-Health advantages and benefits.
- From an education perspective, there is a need to inform doctors and healthcare providers of the latest technology developments and what can be achieved by adopting future systems based on them.
- From a legal perspective, ethical issues of mobile healthcare services need to be addressed and decided.

In the social context, constant connectivity may be instant but medical treatment of an individual patient is only really effective if it is specific to that patient rather than to the population as a whole. For example, a patient is given the correct dose of the most appropriate drug, taken at specific times and for a particular duration. This is a simplification but it gives the general idea.

Other m-Health challenges and limitations that are still under discussion may be summarized as follows:

- *Lack of Interoperability and Standards:* This will be discussed at length in a later chapter, but essentially it means an incompatibility between the building elements that comprise present mobile technology hardware, medical sensor connectivity, and web access protocols. Furthermore, there is a lack of integration between various medical services that use m-Health to enable access to health records, appointments, drug compliance and administration, referrals, images, and so on. What is needed is a truly integrated "m-Health on demand" universal mode of operation. This is currently being debated by international organizations such as the WHO and the International Telecommunications Union (ITU). Particular effort concerns the impact of M2M communications, for which standards for m-Health services are being finalized.
- *Security and Privacy:* There is increasing demand to develop robust and secure approaches for improved security and privacy of medical data transmitted in m-Health connectivity channels. This is a challenging issue that is currently being addressed by major research and industry institutions.
- *Medical Working Practice and Acceptability:* It is generally difficult to implement any major *modus operandi* in traditional medical practices and hospitals, especially the adoption of new and unproven technologies. This is not necessarily due to staff obstructiveness, or their reluctance to accept changes in working practices, but more because of the layers of complex bureaucracy and organization, together with pressurized schedules, lack of incentive, and a lack of appreciation of any benefits, including cost-saving and better use of time.
- *Business Models and Ecosystems:* There are to date no clear business models for m-Health but only sporadic models. It is difficult terrain to navigate as there is clearly no overarching evidence that a single m-Health business model can work

for different applications and services. Payment and revenue models change from one case to another. This is a challenge that has been addressed extensively by the different telecommunications and service providers that have embraced m-Health systems. However, there are success stories of business models that are working, otherwise how can the huge level of investment, estimated in billions of dollars in this domain, be justified?

There are other factors relating to the technology hype cycle, and the current position of m-Health within the innovation cycle is open to further debate and discussion. These and other issues and barriers for larger deployment of m-Health services globally will be considered in more detail in later chapters.

1.7 SUMMARY

Since the introduction of the concept over a decade ago, m-Health has become one of the four domains of ICT for healthcare. Some would argue that it is the key domain due to its fundamental link with our digital and mobile world. Clearly, mobile health is now not only a mere ICT for health domain but also a science in itself. It represents how technology and related advances in mobile communications, Internet technologies, and medical sensors can better serve medical and healthcare provisions. However, there is ongoing debate and opinions about the exact meaning of m-Health and its role in future healthcare services and well-being applications.

The role of the current 4G and future 5G communications and network technologies, and other wireless technologies and their connectivity with smart wearable sensors and cloud computing platforms, will play an increasingly pivotal role in m-Health systems that will be part of everyday life for many people in the near future. Understanding people's social and behavioral response toward the acceptance of this generation of smart mobile computing and network systems is an important advance in this evolutionary process. Another advance will be the future interface architectures of smart M2M communications and IoT for m-Health that will potentially lead to the development of a new generation of social networking and intelligent computing connectivity care models. The era of a successor, m-Health 2.0, is evolving from these developments. However, all challenges will not be fully realized without bringing together the multidisciplinary areas of medicine, psychology, sociology, economics, engineering, and computer science to achieve the full potential and impact of m-Health that we alluded to in the beginning of this chapter.

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