Chapter 18
mHealth: Smart Wearable Devices and the Challenges of a Refractory Context

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Abstract The development of smart wearable devices has strengthened a new area: mHealth. This is characterized by the use of mobile technologies for the diagnosis, monitoring, and intervention of health conditions. When inserted into the wider universe comprising the Internet of Things, mHealth solutions emerge with real-world applications. The myriad of mHealth-based applications already draws a scenario in which these new technologies will be responsible for changing the current logic of healthcare delivery. Nevertheless, there are numerous challenges for mHealth before its full potential can be realized. The Brazilian context is marked by peculiarities regarding the challenges for the dissemination of mHealth. There are few professionals, resistance to adopting new health technologies, an inexistent regulatory framework, regional inequalities, the absence of guidelines for protecting personal data, and difficulty associated with communication networks. Such aspects are discussed throughout this work together with components relating to the current status of development linked to mHealth.

18.1 Introduction

Today we live in a connected world. There are about 5 billion mobile phones in the world, roughly 1 for every person over 15 years old (Slovensky and Malvey 2015). Wireless connectivity allows us to access information and communicate anywhere and at any time. These characteristics of the modern world have contributed to

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changing the way we work, play, and live. The impact of the Internet has irreversibly reconfigured our way of life. The implications of these innovations, associated with the possibility of unlimited communication, also resonate with health, clearing the way for the spread of mHealth. This term, coined over 20 years ago by Robert Istepanian, summarizes the new possibilities for the supply and consumption of health services facilitated by ubiquitous connectivity (Istepanian et al. 2010). Despite the many definitions of the term, it can be understood as the provision of medical services and/or public health, which use the technological support of mobile devices such as cell phones, sensors, and other smart wearable devices directly connected to the user, for monitoring or the administration of health interventions (WHO 2011). Smart wearable devices are used in equipment adjacent to the body, which are able to monitor various health parameters as well as perform health interventions.

The concept of mobile health (*mHealth*) is intricately related to the unfolding of another technology called the Internet of Things[1] (*IoT*, acronym in English). *IoT* refers to the use of devices with Internet connection capability, allowing them to interact with other devices, services, and/or people with large scale-up possibilities (Mukhopadhyay 2014). The term *IoT* was first proposed in 1999 by Massachusetts Institute of Technology (MIT). At the time, the definition was understood as the extension of communication skills to things, allowing them to communicate with each other and with people (Ashton 2009). Put differently, *IoT* allowed devices and equipment that were once isolated to interact with each other and with the Internet in an integrated fashion. Thanks to the large number of devices and applications, by 2030 *IoT* is expected to exceed people as the largest producer of information on the Internet (Evans 2011).

The concepts of the *IoT* and mHealth cluster together under a broader term linked to health: eHealth. This refers to the provision of health services remotely, built on technologies such as the Internet, smart wearable devices (SWDs), electronic medical records, telehealth, *cloud computing*, and smartphones. *mHealth* is an integral part of this ecosystem by bridging mobile solutions and *IoT* technologies services via smart wearable devices.

The applications of mHealth-based solutions are diverse and have the potential to revolutionize the way health services are performed. During the next coming years, the traditional ways of providing health services will be profoundly modified. For example, the ubiquitous availability of medical records is possible thanks to cloud storage solutions (*cloud computing*). Health professional consultations may be held electronically, with diagnostic and therapeutic information as readily available as current in-person consultations. Specific laboratory tests are no longer required since "electronic testing devices at the point of care" (DTPC) are able to collect laboratory data. This noninvasive approach possesses the same accuracy as traditional methods and can be used repeatedly. Preventive interventions, based on

[1] This aspect is also discussed in Chap. 21, which addresses the topic of the Internet of Things (IoT) applied to health in Brazil.

models of artificial intelligence, will be prioritized to prevent the occurrence of acute episodes. These are only some of the numerous possibilities.

When discussing the elements that characterize the concepts of mHealth and the *IoT*, it is crucial to understand the challenges that govern the Internet of Things. These obstacles impact the spread of mHealth solutions, especially in the Brazilian context. Therefore, it is necessary to examine the current state of both issues in relation to each other. The task of mapping the state of mHealth is challenging given the relevance the topic has received in the last 10 years. Initial attempts to trace the literature on the subject allowed us to understand the complexity of the subject and the breadth of the current scientific literature at the global level. Nevertheless, the topic is emerging within the Brazilian context. Thus, to contextualize the discussion, we decided to carry out a literature review to map out existing studies. This allowed us to better comprehend the use and development of mHealth solutions. From this, it was possible to approach the Brazilian reality in its nascent state regarding the use and development of mHealth-based applications.

After delineating the existing state of the field of mHealth, the different roles of multiple agents that operate in this field will be analyzed. Additionally, we will examine the developments already materializing in the field of mHealth which will have the potential to modify the logic of providing health services over the next few years. We will also address the challenges present in Brazil's local reality and how they relate to the prospects of incorporating solutions based on mHealth.

18.2 An Overview on Health Mobile Technology (mHealth)

Given the recent nature of the studies dedicated to mHealth, it can be said that research groups, universities, companies, and other *stakeholders* in this ecosystem occupy relatively nascent positions. A *stakeholder* is an individual, group, institution, or organization with the ability to affect the operations and success of the other agents inserted in a given ecosystem. They are also likely affected by the decisions and actions of other agents in this ecosystem (Slovensky and Malvey 2015). The relationships between the different *stakeholders* in health are much more reciprocal than unidirectional. In this sense, the evidence on the impact, degree of relevance, and relative importance in the field are still scattered or in the consolidation phase. There are several agents producing information about mHealth albeit not as a unified front. Nevertheless, it is already possible to identify countries, researchers, and centers starting to collaborate in the area.

To provide an overview of key *stakeholders* in the context of mHealth, we draw on a recent study conducted by Sweileh et al. (2017) who performed a bibliometric analysis of everything that has been produced on mHealth between the years 2006 and 2016. With this, it was possible to identify the key players leading the development of the field, their location, affiliated institutions, and partner networks.

Bibliometrics can be understood as a statistical method used to evaluate the quality and quantity of literature produced in a given context (Santha kumar and

Kaliyaperumal 2015). It also helps to identify trends, impact analysis of works by citations, and national and international contributions to a body of work in a field of study (Fatehi and Wootton 2012). Specifically, Sweileh et al. (2017) analyzed the following dimensions within mHealth: growth in the number of publications, contribution of each country, international collaboration, analysis of impact through citations, main authors and universities, and main communication channels on the subject. The data were extracted from *Scopus*; 5,464 papers were summarized. From this study, it can be seen that the volume of work has increased significantly in the 10 years analyzed. The number of papers published per year has increased almost tenfold, which points to the growing debate on mHealth and its potential applications. The increase of available data, greater propensity of *stakeholders* for the development of pilot projects, and dissemination of the importance of proper information management for designing strategies aimed at problem solving may be considered *proxies* for increasing work on the subject.

Additionally, the main topics covered in each study were processed and categorized to allow for network analysis (Sweileh et al. 2017). Creating the networks allows for an analysis of related themes, main categories, and relationships between the different actors.

As for the themes related to the papers, it is possible to highlight the management of chronic conditions as well as applications related to mental health, disease prevention, and physical activity. For chronic conditions such as diabetes, self-management was a recurrent topic in the works analyzed. Adherence to treatment was a cross-cutting topic that was related to disease prevention and also for the control of chronic conditions such as diabetes and hypertension. Solutions for the cessation of tobacco use and applications related to mental health were addressed by several of the studies considered in the analysis. Finally, there is a need to highlight issues associated with weight control, physical activity, and health promotion. Several important topics related to prevention have yet to be satisfactorily addressed by previous studies. These include the health of workers and neglected diseases. This gap suggests there is a potential niche for further discussions and for contextualized propositions that are currently lacking.

Canada, the United States, the United Kingdom, Australia, South Korea, India, Germany, China, Spain, France, the Netherlands, Switzerland, and Sweden have made major contributions to the study of mHealth. The two biggest contributors were the United Kingdom and the United States. These two countries have established themselves as leaders in the production of scholarly studies on mHealth, responsible for producing more than 40% of all studies reviewed by Sweileh et al. (2017).

There is significant overlap between the countries with the most published studies on mHealth and the location of the most outstanding institutions. Prominent research centers in mHealth are mostly located in the United States and Canada. Nine of the top 10 centers are located in these two countries. Another topic of interest is the major presence in the list of research centers in the world, mainly by universities. The main channels of communication on mHealth are the leading scientific journals. The most influential channel on mHealth is the *Journal of Medical Internet Research*. Others with considerable influential are *Artificial*

Intelligence in Medicine, *JAMA*, *American Journal of Preventive Medicine*, *Lancet*, *and PloS One*. There is also a prevalence of international journals, renowned in other areas, serving as consolidated media outlets on advances relating to mHealth.

The international studies on mHealth are extensive and have been taking place for a few decades. In the Brazilian context, however, there are studies on the subject. For one, there are few studies on the subject published in Portuguese (Rocha et al. 2016). A January 2018 survey, performed on Brazilian publications registered in the electronic database SciELO (standing for Scientific Electronic Library Online), found only two papers addressing the theme of mHealth. In addition, there is a refractory stance by institutions, academics, and policy makers on the subject. The best journals in Brazilian healthcare lacked publications on mHealth until the latter portion of 2017. The pioneering nature of this type of technology, coupled with the lack of debate in the Brazilian context, has relegated the discussion of mHealth's potential in Brazil to a secondary level (Rocha et al. 2016).

In Brazil, the overall scenario, despite the occasional initiatives, is the lag time of local scholars in relation to the level of debate that exists in the international context. The scientific communication streams in Brazil, especially those in the health field, are marked by a traditionalist stance and resistant to debates on innovations. In addition, corporatism restricts researchers from discussing innovative and unexplored themes in national literature. Thus, the stance adopted by Brazilian media outlets screens out new debates and discussions that are not part of what is traditionally discussed in the national scientific scenario. The result is a self-absorbed debate, with little propositional capacity, which seeks to legitimize itself to ensure its perennial character.

The current position of the popular science media delays more fruitful discussions that have a great disruptive potential. This eventually affects the formation of new opinions in the Brazilian context, hinders the dissemination of innovative technologies, slows the inclusion of innovative themes in the context of health policies, and fosters dependence on foreign knowledge. Only in the last 2 years do we see debates on mHealth-based applications and projects discussed on the national scene. Few of the initiatives by research groups are dedicated to examining the impact of mHealth solutions on health in the Brazilian context.

Despite the refractory academic context, there is a thriving reality regarding startups. There are several companies working in the mHealth sector that are trying to produce solutions to manage the challenges of caregiving in the context of the *IoT*. There are initiatives dedicated to including electronic medical records, management of medical services, development of *devices*, genomics, population management, engagement of patients, Big Data, developing *apps*, telemetry, wellness, and health marketing (Belle et al. 2015; Bissonnette and Bergeron 2017; Gatzoulis and Iakovidis 2007; Grossglauser and Saner 2014; Handel 2011; Martin 2012; Nicholas et al. 2015; Soh et al. 2013; Srivastava et al. 2015; West 2012).

The next two decades will witness an unprecedented revolution in the way health services are delivered. Their impact on the provision of health services will vary to differing degrees. It is expected that there will be an improvement in health conditions observed today. We will examine the central agents of this process and their associated limitations and potential.

18.3 Role in Disruptive Technologies in Health: Key Stakeholders Involved in the Development of mHealth Solutions

A first step to better understand the *stakeholders* active in a given context is to classify them according to similarity of activity or source of power. In a simplified way, the sources of a *stakeholder's* power come from one or more of the following: control over necessary resources, mastery of critical skills for the design and operation of processes, position as required service provider, holds political influence, has veto power, and is responsible for large volumes of purchases or financial transactions. We can construct the environment for mHealth by taking into account these sources. The main *stakeholders* in this scenario would be: patients, either as individuals or organized into groups; doctors and other health professionals; institutions providing care; agents responsible for care cost coverage, such as government and healthcare operators; pharmaceutical corporations; technology companies; and providers of communication services (Slovensky and Malvey 2015). All these agents act interdependently, contributing to the characterization of the mHealth ecosystem. This typology of *stakeholders* involved in the mHealth ecosystem is only an approximation in defining categories for the main agents operating in this ecosystem.

18.3.1 Patients

The main items valued by patients seeking health services, with respect to mHealth, are healthcare solutions that simplify the resolution of current problems. Complex solutions that increase the difficulty of monitoring biomedical parameters, release impertinent warnings, and/or have a high learning curve are classically abandoned by end users (Slovensky and Malvey 2015). Patients are faced with a very large volume of smart wearable devices, medical information, and *apps* for monitoring health conditions. Nevertheless, those solutions with empowering features that simplify the troubleshooting process associated with obtaining care and improving access to medical care get a higher degree of acceptance (Siau and Shen 2006).

18.3.2 Doctors and Other Health Professionals

Historically, doctors and health professionals have assumed been spokespersons regarding therapeutic strategies and the provision of health-related information. Technology has changed these roles and empowered healthcare consumers with information not previously available. mHealth will only encourage this trend, since not only clinical information will be more accessible but also reliable data for diagnosis. The availability of accurate information that will allow the patients

themselves to be guided by the nuances of differential diagnoses will require a reconfiguration of the roles played by health professionals.

Medicine is an area resistant to the incorporation of new technologies. Not only will the relationship with patients be adjusted but also the way professionals perform their daily activities. It will no longer be necessary to have backup diagnostic and therapeutic support services in the manner that exists today. Professionals will be able to test and examine multiple diagnostic possibilities with data from biomedical markers directly in their offices. Especially for simpler questions, doctors will not need to develop third-party services. The increased use of smartphones in the clinical setting is already a proxy for this trend (Nerminathan et al. 2017). A study conducted by a research institute in Florida found accessing electronic medical records by primary care physicians on their *tablets* or smartphones has increased significantly, indicating that professionals have chosen to get access to their patients' medical information using a cloud platform. This type of platform is similar to those that mHealth telemetry centers can provide.

Stakeholders interested in the development of mHealth solutions must be prepared to overcome the obstacles that are still present, especially in relation to resistance by health professionals in using technology-based solutions. Evidence from recent studies show an emerging trend for the dissemination of solutions based on mHealth. This scenario, however, is not yet completely set, and the resistance of some professional groups represents a hurdle. Slovensky and Malvey (2015) pointed out that among the medical specialties, those most resistant to the incorporation of new technologies are orthopedists, ophthalmologists, and otolaryngologists. Moreover, these authors pointed out that government incentives to encourage new technologies in the workplace have been effective in raising the awareness of previously resistant groups on the importance of adopting new solutions. This may be a way to facilitate the spread of mHealth applications.

18.3.3 Care Providers and Health Systems

Health service providers are strongly vested players in the massification of mHealth solutions. Initiatives have been undertaken with the objective of increasing the use of mHealth applications, as these have the potential to improve the quality of life of patients with a concomitant reduction in healthcare provision costs.

The ability to monitor biomedical markers continuously and link the results to electronic medical records with unique identifiers opens the possibility of implementing *healthcare analytics* solutions for performing predictive analysis. Such analyses can be used to stratify the risk of a given population or user profile, design interventions for health promotion and disease prevention, and prevent medical complications from acute episodes such as stroke, heart attacks, or amputations.

Many companies have taken advantage of this niche. The development of predictive solutions dedicated to minimize care supply costs has been met with euphoria

by the market and has spurred the development of startups. Companies like Weltok[2] have adopted an aggressive procurement policy to cover the widest possible range of services associated with providing predictive healthcare solutions in the United States.

In Brazil, initiatives of this nature are limited, but there are already some startups such as Hekima[3] and Pyron[4] health seeking to develop solutions in the health arena.

For health systems, the benefits are even greater due the volume of care and the potential benefits that can be earned for the population as a whole. In terms of spending, the potential savings as well as improvement in people's quality of life are significant.

In Brazil, a solution for electronic medical records has been in development for some years, the SUS card (Ministry of Health 2015). The idea is to provide a national health record number to each user of the public system in order to monitor patient demands more accurately. This type of health data management device opens the possibility of developing population health monitoring applications for injury prevention capabilities and health promotion.

The health minimum data set (CMD[5]) unites nine systems within SUS: Outpatient Production Bulletin (BPA), Outpatient Procedure Authorization (APAC), Registration of Ambulatory Health Actions (RAAS), Hospitalization Authorization (SISAIH01), Collection Communication Hospital Information and Outpatient (CIHA01), Outpatient Information System (CIS), Hospital Information System (HIS), Hospital Information Communication Processing and Outpatient (CIHA 02), and Regulation System, Control and Evaluation (SISRCA) (Ministry of Health 2017). All public and private health facilities in the country will record information for the minimum data set. The data can be sent through the existing systems that will be integrated into DATASUS. The availability of such data will create opportunities for new applications developed for SUS such as solutions based on predictive analytics.

18.3.4 Institutions

The pharmaceutical industry is considered an important agent in the context of mHealth due to its heavy investments in research and the substantial volumes of financial resources involved (Slovensky and Malvey 2015).

The development of innovative solutions for the treatment of diseases passes through research on new drugs and the use of nanotechnology to a more effective model of drug administration (Reddy and Aggarwal 2015; Rodrigues et al. 2016). The disruptive potential of these solutions is immense, and the way medicines are

[2] Welltok, Inc.: https://welltok.com/analytic_services/.

[3] Hekima: http://www.hekima.com/.

[4] Piron: https://piron.co/.

[5] All system acronyms are in Portuguese.

discovered, prescribed, marketed, and managed will change substantially over the next few years due to innovations associated with mHealth. There are already smart wearable devices that can deliver drugs in response to metabolic changes in real time. In addition, there is a whole range of innovative solutions in health supported by nanotechnology. Clinical protocols have been impacted as drug treatments are reinvented. Thus, drug therapies will be modified in light of new possibilities for drug administration and dosage control.

18.3.5 Technology and Private Business Investors

The environment for developing new applications anchored in information technology requires its own logic. The creation of startups, applications, and platform solutions or services usually receives support from incubators and accelerators looking to equip entrepreneurs with the skills needed to increase the chances of business success.

There are several funds dedicated to financing good ideas in health. There are global initiatives in this direction with possibilities on almost every continent. The study on the action plan designed for the *IoT* in Brazil contains an entire section analyzing and comparing research funding initiatives in *IoT* worldwide (National Development Bank 2017). In Brazil, there are government-based financing initiatives with the National Development Bank (BNDES) and Finep Startup Program (as known as the Funded Studies and Projects).

The quest to make the ideas developed in the startup environment more concrete has produced some interesting results, especially in solving practical problems in a scalable way. Some startups have been devoted to the development of hardware solutions with quite impressive results. Bragi[6], a German startup, is a prime example. A challenge for disseminating smart wearable devices is the ability to capture multimodal biomedical parameters. This type of capture allows data from multiple sensors to be collected simultaneously, creating new monitoring possibilities. Few smart wearable devices have this ability, and it is critical toward improving quality of information generated by *IoT* devices dedicated to health. The potential associated with mHealth cannot transcend the realm of promises without this kind of data capture since interoperability between solutions is an obstacle. Bragi developed a headset with multimodal capability, long battery life, and superb ergonomics at reasonable price. The device, called DASH, embodies what smart wearable devices need to be in conceptual terms. Thus, some initiatives are already providing real-world solutions with the potential to capture the promise associated with mHealth.

The role of private investors and technology companies within mHealth is to address and overcome challenges in hopes of achieving the full potential of the field. There are numerous technology giants such as Google, Amazon, IBM, Oracle, Samsung, and Apple with health initiatives. The epidemiological transition process

[6] Bragi: https://www.bragi.com/.

across the globe has increased attention dedicated to health as a potential source of financial gains.

Finally, a challenge that is still present is demonstrating the potential to monetize innovations associated with mHealth. Because it is a new technology, there are still no validated business models. As a result, some investors prefer to adopt a more conservative stance with orders placed for mHealth solutions. The ability to prove profitability is linked to demonstrating results that can add value to the *stakeholders* involved. This is another peculiarity related to the issue of private investment (Slovensky and Malvey 2015).

18.3.6 Providers of Communications Services

mHealth depends fundamentally on a solid communication infrastructure. Without it, the possibility to transmit data reliably and in real time is lost and, with it, one of the main benefits from this type of technology. The role associated with communication service providers is crucial to enable the spread of mHealth.

The infrastructure available in most parts of the globe is precariously positioned to support the transit of information according to the standards required by *IoT* solutions. Overall, there are still issues to be addressed in order to provide an adequate environment for reliable data transmission. Without proper management of these circumstances, the widespread dissemination of mHealth applications will be constrained by barriers related to access and the quality of communication services.

The evolving situation is complex, marked by multiple agents shaped by several determining factors. It is critical to understand how different *stakeholders* adjacent to mHealth are intertwined in order to establish partnerships, select trends to monitor, and mentor opinion leaders. Knowing the different *stakeholders*, their aspirations, importance, and networks is fundamental for creating more favorable conditions in the management of an unstable environment as seen with mHealth.

It is possible to envision a series of modifications to the provision of healthcare resulting from the influence of the aforementioned agents. So, we will examine how the technologies linked to mHealth can make changes and analyze the different *devices* for intelligent monitoring of health conditions.

18.4 Potential Associated with the Smart Wearable Devices: New Perspectives of Care

The current provision of health services will change considering the ongoing diffusion of smart wearable devices. From a population perspective, SWD can facilitate the dissemination of health information, improve epidemiological surveillance aspects, and expand the volume of data available for research. They will also encourage improvements in the organization of healthcare networks, service utilization

profiles, and access parameters that can be modeled in real time based on geolocation data.

Interventions for health promotion and disease prevention can be made based on predictive information from the analysis of patients' biomarkers. Such an approach will help to minimize the negative consequences of acute events such as complications associated with diabetes, hypertension, and acute coronary syndrome. In addition, patients may take a more active role with their care. Data collected by smart wearable devices can empower patients leading to more precise management of chronic conditions. Doctors will be able to monitor their patients continuously, leveraging time series data. This is an upgrade from intermittent laboratory tests which do not allow accurate situational monitoring. Additionally, thanks to telemetry monitoring, patients being transported in emergency mobile units can be received in the emergency centers with backup infrastructure already adjusted for their health needs.

Salient procedures for the diagnosis of diseases can be performed directly in health facilities, or even in homes, since there are already devices that can monitor noninvasive biomarkers. The use of nanosensors will contribute to expanded diagnostic possibilities. They can be performed in real time, involving diseases such as cancer or infectious affections. Lifestyle patterns can be linked to biomedical markers assisting professionals and patients in outlining the best strategies for chronic disease management.

Figure 18.1 highlights four main areas and the different existing capacities related to smart wearable devices with respect to mHealth's potential.

In the second half of 2017, 406 *devices* from 273 different companies were mapped as smart wearable devices for external use only. Of this group of 273 companies,

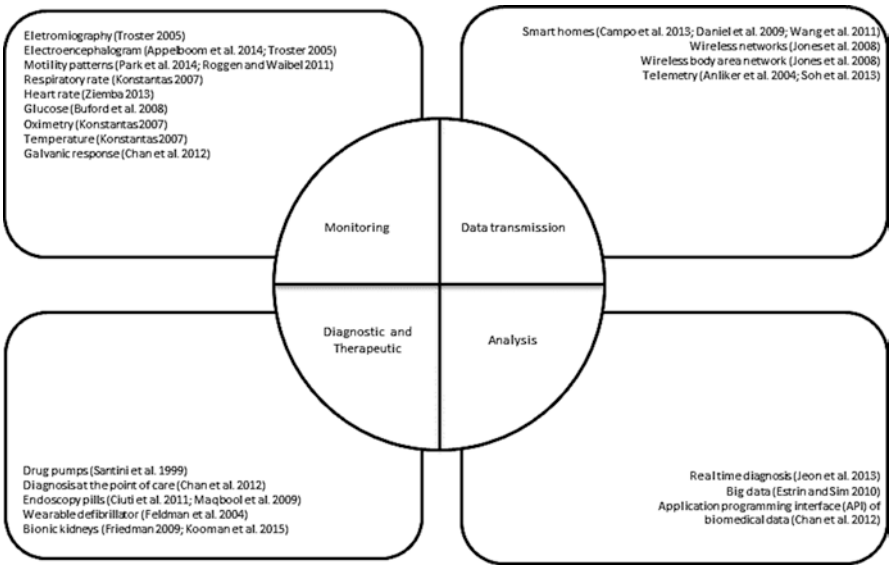

Fig. 18.1 Established possibilities for smart wearable devices. (Source: Rocha et al. (2016))

51 manufacture more than 1 device. The complete list of *devices* currently available can be accessed at: https://vandrico.com/wearables/list. This list of devices has been built collaboratively and has a satisfactory coverage mapping out solutions and updating data. The list provided in this website is extensive, but not exhaustive. There are few systematic initiatives that map out all the devices due to the industry's rapid production of new products, which makes it difficult to maintain a current central repository. There are some works, such as Chan et al. (2012), which sought to provide an overview of existing technologies and manufacturers. This work, however, is becoming dated given the rapid innovations within the field.

These innovations represent the initial steps of the revolution that will be promoted by the expanding use of mHealth solutions. The main advantage associated with this type of technology is linked to the use of information. mHealth creates the basis for the development of *healthcare analytic* solutions by making continuous data capture possible. Part of an incipient scientific field called data science, the domain of *healthcare analytics*, brings together knowledge of computer science, statistics, epidemiology, and public health to transform health data to an effective substrate for care management based on evidence (Reddy and Aggarwal 2015).

The application of analytical solutions has the potential to transform healthcare delivery from being reactive to a proactive approach. The analysis of clinical data based on this set of techniques facilitates the identification of hidden patterns in the data allowing patients to improve their health, professionals to develop unique and more effective therapeutic programs, and managers to organize health systems based on the assumptions provided therein (Porter and Lee 2013).

A new set of techniques is required for proper data management in order for the potential of the Information Age to be reached. Dedicated tools to extract nonobvious patterns from large data volumes belong to the field of "artificial intelligence," particularly from the subsection called "machine learning." This subspecialization allows computer systems to infer patterns from data and can then execute automated activities (Ali et al. 2016). Intrinsically linked to the area of machine learning is another field that deals with the realization of predictive models. Predictive modeling is simply the prediction of future behavior for a particular object of analysis based on past behavior. For this, it relies on data mining techniques and statistical modeling (Shmueli and Koppius 2011).

The adoption of *healthcare analytic* techniques carries the potential to modify existing forms of organization and healthcare provision. There are countless possibilities to capitalize on information and communication technologies in health. At first glance, the benefits to clinical care appear limited to the individual level. However, the mass use of these solutions allows potential advances to expand to the population realm and macro-level management. Despite the potential, the challenges to consolidate this type of technology loom large. There are numerous issues that need to be addressed to allow the dissemination of this set of technologies when examining a global scenario.

The challenges are even greater when one considers the Brazilian context. We will examine the current existing bottlenecks that are slowing the expansion of these innovations.

18.5 The Locoregional Challenges of the Brazilian Context

The Brazilian locoregional challenges that will be presented below are based on the research carried out, with the support of "National Bank for Economic and Social Development" (BNDES), examining the challenges that underlie the country's reality. The ongoing diagnosis by the BNDES highlighted several technological challenges of *mHealth* specific to Brazil: the lack of infrastructure, legal complexity, and lack of skilled labor. So the obstacles to mHealth applications in Brazil are permeated by additional determinants related to our local and regional characteristics.

The first element addressed is about the infrastructure of local communication networks. Currently there are few companies operating in this sector in Brazil, and there is a need for investments aimed at improvements. There is no high-speed Internet coverage throughout the country, and there are regions without any coverage. Expansion is fundamental to enable designs based on mHealth (McKinsey & Company 2016).

Opening the sector to private companies accelerated the process of infrastructure improvement, but not enough to ensure the necessary support for the operational development of *IoT* applications. Current sectoral regulation determines the provision of telecommunication services through grants. Thus, there are unanswered questions about who should receive the grants for *IoT packaged* services. International data roaming is another issue. *IoT* solutions and the associated data traffic do not respect national geographical boundaries (McKinsey & Company 2016). The question of taxation in relation to the services provided is still an unanswered question. The issue of infrastructure will be a bottleneck for the traffic of high-speed information intrinsic to the IoT unless we rethink the current legal framework and construct actions to stimulate communication.

Another critical element pervades the quality of services. *IoT* applications have different requirements in terms of transmission quality, speed, latency, and bandwidth. There is a need to reflect on what niches will demand what type of transmission pattern and with what type of quality. The definition of a single quality standard does not seem appropriate in the *IoT* context, and it will be necessary to differentiate the telecommunication connections and services that will operate as *IoT* infrastructure.

The use of a radio frequency in Brazil requires prior government authorization. Some applications of *IoT* require this scarce good, and it will be necessary to think about strategies to relax the limits of applications for unlicensed frequencies, make use of *white spaces*, and consider the possibility of promoting the relocation of tracks (McKinsey & Company 2016) .

The approval of equipment also limits the adoption of telecommunications solutions in Brazil. The work of the National Telecommunications Agency (ANATEL) only allows approved equipment to be marketed. The advent of *IoT* is expected to produce a significant increase in the amount of applications to be examined for approval. This process, which can take months, represents a bottleneck for adopting new solutions. There is a need to rethink this process, maintain speed, and ensure security and interoperability levels (McKinsey & Company 2016).

As for IP systems, migration from IPv4 to IPv6 is not yet fully complete in Brazil. IPv6 is essential for the connection of *IoT* devices (McKinsey & Company 2016). It is important to examine what obstacles remain and take measures to overcome them. The volume of devices to be registered will constantly increase in the coming years with no prospect that they level off.

Interoperability standards are another key point in the Brazilian reality. Standard requirements are often based on an attempt to avoid lock-in practices. However, agents have been left to themselves to define the standards to be used. This has fostered an environment of competition and no standardization. The lack of standardization hinders integration of solutions between different manufacturers, making the development of applications difficult. The regulatory standards are not healthy, and the lack of intervention has resulted in obstacles for the development of integrated applications in Brazil.

The Brazilian legal scenario adds another nuance to an already complex context: the absence of specific legislation on personal data protection. The absence of this regulation creates an unsafe environment for users and companies that can negatively impact the development of *IoT* applications. The need to develop a framework that protects users without stifling the industry is a technical and political challenge still unresolved (McKinsey & Company 2016). Government regulation has emerged as a constricting factor of innovation. Barriers erected by laws, agencies, and regulations have hindered faster adoption of *IoT* solutions and, as result, mHealth.

From the business point of view, there are no tested and validated models relating to mHealth which could serve as a guide for investors and entrepreneurs. There is little evidence of the ability to monetize the technologies, gaps in consumer perception persist, and there are no studies demonstrating the effectiveness of mHealth-based solutions (Slovensky and Malvey 2015). Another characteristic feature of the health sector is resistance to adopt disruptive technologies (Christensen et al. 2000). Slovensky and Malvey (2015) show that the average time for an innovation to become a clinical standard is 17 years. This culture reflects the stance of the medical professional community, who tend to take a more conservative position when adopting innovations (Slovensky and Malvey 2015).

mHealth solutions are commonly made using a top-down approach. Changes are promoted by a person with hierarchical authority with the purpose of ensuring that health professionals adopt policies, protocols, and preestablished workflows. As such, many programs miss an opportunity for improvement by leaving out health professionals and patients in the design of projects and implementation. Adaptability increases when end users are part of the process (Whittaker et al. 2012). Brazil is not immune to these problems as there is resistance from local agents on the incorporation of technologies associated with mHealth and *IoT* (POETAS.IT 2016).

Finally, the biggest challenge existing in the Brazilian reality is human. Applications of eHealth and *mHealth* have great promise to improve global health. As these projects develop, managers need to be aware of the need for an adequate labor force that enables its implementation and understand healthcare, information technology, communication channels, the people involved, and the organizational challenges.

Despite these needs, what we see is a labor shortage. According to the *World Health Report* of 2006, a health workforce deficit was documented in 57 countries, the worst scenario being in Southeast Asia (Adibi 2015). According to some national estimates, the world needs more than four million doctors, nurses, pharmacists, laboratory technicians, midwives, community health workers, and other frontline health professionals (Bollinger et al. 2013). In Brazil, the health professional category with the largest deficit is medical. The ratio of physicians per thousand inhabitants in Brazil is close to 2 per 100,000.[7] There are also major internal variations as to the proportion of doctors per capita. The north and northeast regions, which are those of lower economic development in the country, have lower medical rates per capita, while the most developed region has nearly 4 physicians per 100,000 inhabitants (Biffi and Tuissi 2017).

The lack of human resources in the health sector is an identified bottleneck to achieving universal access to quality healthcare. However, there is also lack of training, guidance, and continued educational opportunities for quality healthcare professionals interested in innovation-related training programs (Hersh et al. 2010). More specific health labor market research is needed to better characterize the necessary workforce, along with the roles, skills, and great education levels of workers (Hersh et al. 2010).

The context of the IT professional labor market is similar to that of doctors but with an aggravating factor; they are among the professions with severe professional shortages in the Brazilian and world market. The situation regarding a new category called data scientist specialists is even more delicate.

Brazil has a great need for data scientists, with fewer than 200 professionals across the country. These individuals are capable to handle large volumes of data (*Big Data*), integrate databases, analyze structured and unstructured data, and develop predictive models. All these skills are indispensable features for working with *mHealth*. It is clear that these shortages can interfere with project and program implementation since the competition for this business is fierce (Pereira 2017).

A good data scientist is expert in at least four areas of knowledge: (i) communication, (ii) statistics, (iii) programming, and (iv) business. Demand for data scientists worldwide will exceed the volume of professionals being trained. Moreover, this kind of talent is hard to produce, taking years of training for someone with intrinsic math skills (Manyika et al. 2011).

The remuneration will naturally be an aggravating factor in disseminating the potential associated with the work of data scientist. Moreover, an informal survey of data scientists' priorities revealed something even more important: this professional wants to be the "central command." Considering how difficult it is find and hold onto data scientists, one would assume that a good strategy is to hire them as consultants. Most consulting firms, however, do not have many of these professionals. Even the large companies – Accenture, Deloitte, IBM Global Services – struggle when it comes to supporting *Big Data* projects for their clients. Resources from data

[7] Europe's rate was 3.3 in 2014 (WHO 2015).

scientists who are already part of the team are being applied primarily to more conventional quantitative analysis problems (Davenport and Patil 2011).

Such shortage drives competition for data scientists culminating in many of the professionals opting for large corporations. Microsoft alone has more data scientists than all of Brazil. Countries in distress cannot fill this workforce gap by simply importing talent or changing the graduate requirements and waiting for people to be trained with more skills (although these may be important actions to take). It will be necessary to recycle a significant amount of talent on the spot and invest in education to address the adequacy of professionals in the market.

In short, the *IoT* and mHealth scenario is complex and involves multiple stakeholders. Its complexity is itself part of the object to which the whole context seeks to address. Health problems, too, are complex and multifaceted. Developing solutions to these problems requires coordinated work between different *stakeholders* to create value for both those who consume services and for those responsible for providing care. The challenges associated with technological development of *IoT*, and therefore mHealth, have not yet been fully addressed. Regarding this aspect, Mukhopadhyay (2014) argues that some of the main issues to be addressed are miniaturization, availability of the Internet, the development of sensors for wireless sensor networks (WSN) and radio-frequency identification (RFID), improvement of security and privacy standards, need for cheaper components, fault tolerance, consumption and energy saving, user acceptance, and training of specialists. These issues still present obstacles that have not been completely overcome and that, in some context, end up limiting the potential associated with *IoT* and mHealth solutions. Another key point is the ubiquitous availability of the Internet. Generally speaking, the observed situation is that of a challenging state that requires further ripening.

18.6 Future Directions: What the Future Holds for mHealth Solutions

Despite more than 20 years exploring this concept, we still cannot say for sure where the spread of mHealth will take us. Any such attempt is speculative at best due to the sector's inherent complexity and challenges. What is known is that mHealth is a disruptive innovation, marked by immense potential, since it creates possibilities to reorganize the way health has previously been treated. Despite its recent development, it can be said that addressing the challenges related to mHealth is not done linearly. The structure is more like a ladder in which there are periods of stagnation, followed by abrupt progress (Slovensky and Malvey 2015).

Fitbit applications, for example, emerged as a device for monitoring training. However, recently, with the incorporation of some sensors, they were redirected to follow up variations of blood pressure and heart rate for patients undergoing cardiac surgery (Alharbi et al. 2016). The path that has been trodden by mHealth is no

different from those already covered by other innovations that have an impact on health. In the early twentieth century, the logic of visiting doctors by patients was modified considering the invention of the car (Slovensky and Malvey 2015). Hospitals have become the main locations of complex surgeries, thanks to the availability of support services and diagnostic anesthesia (Slovensky and Malvey 2015). All these changes took time and were gradually incorporated into health frameworks.

The gradual incorporation of new innovations is a hallmark of healthcare. At the beginning of the early 1980s, computers were used in hospitals to perform accounts payable processing procedures and other financial features. The incorporation of such technology to support care was performed only in a second instance. In order to incorporate a technology together with the health services delivery system, there is a need for evidence on the positive impact on improving health outcome indicators, promoting healthier behaviors in the population, increasing patient engagement with the treatment guidelines provided, and improving the efficiency of care delivery (Slovensky and Malvey 2015). For many items, mHealth is still a promise without solid evidence. Nevertheless, the search for such evidence has been increasing, once there is an enlargement of the debate on mHealth and its unfoldings (Sweileh et al. 2017).

Systematic adjustments are needed to catalyze the necessary changes to realize mHealth's proclaimed potential benefits. The first change is related to developing a culture of innovation. This is different from the mere incorporation of innovations (Slovensky and Malvey 2015). A culture of innovation allows simultaneous consideration of the different aspects necessary for a solution to reach maximum potential. This means reinventing the logic of providing care so that it takes into account a different supply system, new roles associated with the players acting in this system, a new operational infrastructure, and any misunderstandings that will be committed throughout the process of improvement.

The future of mHealth is seen today as something fluid, tenuous, and dependent on multiple factors. Nevertheless, the new possibilities arising from this mobility are a trend with no return. Mobility associated with healthcare provides the opportunity to address disparities in care, especially among minorities and disadvantaged populations (Slovensky and Malvey 2015). The strengthening of mobile connectivity solutions related to health is something that will crystalize over the next few years. For the other aspects of this technology, the only certainty is uncertainty.

The Brazilian context and prospects waiting on the horizon are challenging. Overcoming obstacles that exist in our local reality will require coordinated efforts in multiple areas and sectors to allow the design of an environment conducive to the development of mHealth solutions. Aware of the size of this challenge, the first point to address would be to dilute resistance that leaves the Brazilian context refractory to the use and incorporation of new technologies. The health sector has some formidable views, predominantly among professionals, who occupy positions of power. This ultimately leads to the mantra of resistance to change. The unfounded resistance to new changes, given the volume of international evidence,

seems to be based on the need to maintain an already outdated agenda. This stance is only capable of supporting projects and resources in already solidified areas and to the benefit of those in positions of power. Overcoming this first hurdle may create more suitable conditions for disruptive applications to be developed in the Brazilian context.

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