Digital healthcare: Historical development, applications, and future research directions

By: Ravi Sharma and Nir Kshetri

Sharma, Ravi and Kshetri, Nir (2020), "Digital healthcare: Historical development, applications, and future research directions", *International Journal of Information Management* 53, August (102105). https://doi.org/10.1016/j.ijinfomgt.2020.102105

Abstract:

It has been forecasted by the World Economic Forum that by 2040, annual global healthcare spending will be about US$25 trillion (Akpakwu & Seidman, 2018). Technological developments in diverse areas such as the Internet of Things, big data analytics, Artificial Intelligence, Augmented Reality, Blockchain, and mobile technologies are likely to shape how healthcare and other services are delivered, particularly in the developing world (Chandwani, De, & Dwivedi, 2018; Dwivedi, Shareef, Simintiras, Lal, & Weerakkody, 2016; Kshetri, 2016; Wang, Kung, Wang, & Cegielski, 2018). For instance, healthcare is arguably one of the areas with the biggest applications of IoT supported by big data analytics. One estimate suggested that by 2020, healthcare applications will account for 15 % of the global IoT applications (Saunders, 2014).

Keywords: editorial | healthcare | digital health | health technology

Article:

1. Introduction

It has been forecasted by the World Economic Forum that by 2040, annual global healthcare spending will be about US$25 trillion (Akpakwu & Seidman, 2018). Technological developments in diverse areas such as the Internet of Things, big data analytics, Artificial Intelligence, Augmented Reality, Blockchain, and mobile technologies are likely to shape how healthcare and other services are delivered, particularly in the developing world (Chandwani, De, & Dwivedi, 2018; Dwivedi, Shareef, Simintiras, Lal, & Weerakkody, 2016; Kshetri, 2016; Wang, Kung, Wang, & Cegielski, 2018). For instance, healthcare is arguably one of the areas with the biggest applications of IoT supported by big data analytics. One estimate suggested that by 2020, healthcare applications will account for 15 % of the global IoT applications (Saunders, 2014).

The World Health Organization (WHO) defines digital healthcare as "the transfer of health resources and healthcare by electronic means". Digital health has emerged in the past two decades from standalone efforts at digitization of medical records (Williams & Boren, 2008) through the epoch of viability as a digital platform as a service to the current context of health-on-a-cloud anytime, anyplace (Sultan, 2014). Current trends and practices have underscored the feasibility of digital health to emerge as a global service. It is imperative to conceive a 'logic' to organize the resulting "health-on-a-cloud" and to be archived as a state-of-the-art set of trends and practices (Felix & Sharma, 2016). This Special Section serves such a purpose in that it seeks to bring researchers and scholars together in focusing on the critical and current issues confronting the continued growth and development of digital healthcare.

2. This special issue

Given that digital healthcare is not a nascent technology (Sultan, 2014), for this special issue, we specifically invited submissions that make new contributions to theory, methodology *and* empirical results.

This special issue comprises two papers; with one presenting a practice-oriented review and the other on the adoption of big data analytics for healthcare.

The article by Lena Stephanie, Ravi S. Sharma,[1] "Digital health eco-systems: An epochal review of practice-oriented research" looks at the historical development of digital health. The authors provide details of the evolution of practice-oriented digital health ecosystems during 1998–2018 in what they describe as, an "epochal review" of research literature. The authors have explained why this period has been the beginning of a distinctive period in the history of digital health. From the standpoint of innovation, diffusion in digital health, they have identified, explained three major stages during this period. The article promotes an understanding of the evolution of digital health, highlights key developments in the field. It also highlights the substantive areas of inquiry related to the practice of healthcare during the period such as, electronic medical records, health cloud, data analytics, Internet-enabled devices, other emerging information technologies. In scope, the review tracks the evolution of digital health, the seminal developments in the field - crucial to obtain a grasp of the key issues involving the delivery of healthcare 4.0.

The article by Peng-Ting Chen, Chia-Li Lin and Wan-NingWu titled "Big data management in healthcare: Adoption challenges and implications" identified several significant barriers to big data development in medical institutions and utilised an analytic network process (ANP) approach to construct appropriate strategies for overcoming such barriers. They concluded that: while many medical institutions have encountered failure in adopting medical big data systems, many of these barriers are closely related to human expertise, resource allocation, operational procedure, laws and regulations, and market access capability. Until and unless medical institutions withdraw these barriers with appropriate strategies, the adoption of big data systems in healthcare would not yield optimal outcomes.

The two articles in this special issue, understandably, do not provide a comprehensive and detailed coverage of trends and future directions of digital health. In the following sections, we attempt to fill some of the gaps with a strategic account of the landscape.

3. Key issues shaping the digital health landscape

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[1] The Editor in Chief, Yogesh Dwivedi, handled this submission with Guest Editor Nir Kshetri.

Several key trends are emerging which will shape the nature of the digital health landscape. While this special issue covered a number of important issues transforming digital health, it could not cover many of the integral issues facing this evolving technology. We focus on two major trends regarding the generation and use of digital health applications: a) The Fourth Industrial Revolution and Healthcare, and b) Digital health and the poor–rich divide in the access to healthcare services.

3.1. The fourth industrial revolution and healthcare

Radical innovations and technologies have brought about a fundamental shift in the healthcare industry as well as other sectors of the global economy. This phenomenon is commonly referred to as the Fourth Industrial Revolution (4IR), which can be attributed to disruptive technologies such as blockchain, big data, Internet of things, artificial intelligence, autonomous vehicles, remote sensing (satellite imagery and drones), wearables, robotics, genome editing, augmented reality (AR), 3D printing and biotechnologies. A further observation is that many technologies related to 4IR are converging. We illustrate the potential revolutionary power and nature of the 4IR with three key technologies that are transforming digital health: artificial intelligence (AI), blockchain and genome editing.

3.2. Artificial intelligence in healthcare

AI is among the most powerful technological innovations that is shaping the healthcare system. Among major benefits, AI applications have made possible to perform things that human providers are not capable of doing. They have also helped automate labor-intensive, menial and dull work such as dealing with electronic records and typing on keyboards (Price, 2019). Even in tasks such as such as reading radiology images, AI outperforms humans in some key aspects (Dickson, 2017).

It is increasingly the case that medical AI can do things that even the world's best medical professionals cannot perform. For instance, AI can possibly analyze a patient's symptoms and other vital signs. The algorithms then compare the information with the patient's history and those of their families as well as millions of other patients. In this way, AI can find the causes of the illness much faster and with a high level of accuracy (Dickson, 2017).

3.3. Blockchain in healthcare

Among key benefits of blockchain in healthcare is that the technology is capable of providing a higher degree of security, privacy and confidentiality of healthcare data. This benefit becomes especially important if we consider the fact that many healthcare organizations lack mechanisms to ensure that patient data are not accessed by unauthorized users (Kshetri, 2017). Moreover, current electronic healthcare record (EHR) infrastructure may not be sufficient to meet patient privacy requirements. Blockchain is viewed to have the potential to address these challenges by solving the broader problem of systems relying on password-based security and authentication. Blockchain can arguably improve identity and access management, which involves controlling information such as patient identity on computer networks (Kshetri, 2018). Since inter-operable, EHRs at the core of this concept (Williams & Boren, 2008), one of the key benefits of blockchain is likely to be in eliminating inefficient procedures to transfer data across healthcare services providers (Kshetri, 2018). In this way, it can promote the interoperability of EHRs. Such benefits can be even greater for developing countries, which face is the lack of interoperability of healthcare apps (Tran Ngoc, Bigirimana, & Muneene, 2018).

Prior research has suggested that blockchain is also likely to have an intriguing impact on precision healthcare (PHC) (Sharma, Zhang, Wingreen, Kshetri, & Zahid, 2020). PHC entails the development of models to link individual EHRs to the population in order to derive the benefit of aggregating EHRs with consideration to social context (Colijn et al., 2017).

3.4. Genome editing

Genome editing involves making changes to the DNA of a cell or an organism. This process allows scientists to test how specific genetic variations generate particular traits and diseases (Schwab, 2016). A key benefit of genome editing stems from the fact that by observing the patterns in huge datasets of genetic information and medical records, it is possible to examine mutations and linkages. This information can be used to effectively personalize the treatment and process protocols for a patient. In the case of chronic disease, this process will play a critical role in increasing a treatment's efficacy (Machaiah, 2017).

Genome editing is finding ever-increasing uses in digital health. The global genome editing market was US$ 3.19 billion in 2017, which is projected to increase to US$ 6.28 billion by 2022 (Sustainia, 2018). This growth is associated with and facilitated by rapidly decreasing costs and faster mapping time. In order to sequence a person's genome, doctors first collect blood or saliva that has the DNA. Chemicals are used to gather the DNA by opening the cell membranes. Sophisticated machines are used to read the genetic material. About three billion base pairs that make up a person's genetic code need to be read (Rochman, 2012). Due to the huge amount of information and complex processing involved, the first sequencing of the whole human genome in 2003 cost about $2.7 billion. The process took 13 years for thousands of scientists. Due to the availability of faster computing capabilities, time and cost have significantly reduced since then. In 2018, it became possible to map a person's genome 30 times in 40 h so that any scanning errors can be eliminated. It cost less than US$1,000 to do so sandoz.com, 2018). The U.S. company Illumina, which develops, manufactures, and markets systems for the analysis of genetic variation and biological function, estimates that the costs will soon reduce to less than $100 (Buhr, 2017).

3.5. Digital health and the poor–rich divide in the access to healthcare services

The poor–rich divide in access to healthcare services, which is also referred to as the global health divide (Kickbusch, 2001) is a key challenge facing the world today. According to the World Health Organization, developed countries account for 90 % of the global healthcare resources (World Health Organization (WHO), 1998). This divide is associated with and facilitated by two other divides: education/skill and the digital divide (World Bank, 1998). Each of these interrelated divides currently hinders attempts to provide healthcare services to poor people.

3.6. Overcoming the barriers to access for healthcare services

In many developing countries various barriers to digital health are being overcome. A key barrier that impedes the development of digital health is the policy environment (Labrique et al., 2018). Inefficiencies and misalignments stemming from the lack of proper policy and coordination among various stakeholders and the lack of sustainable funding critically impede healthcare organizations 'ability to benefit from digital healthcare initiatives (Labrique et al., 2018; Tran Ngoc et al., 2018). In many developing countries, regulations such as those related to patient data privacy are less stringent than those of developed countries, which can act as a facilitator to the diffusion of digital health technologies. Observers have also noted that healthcare markets in many African experience lower interference from the government compared to many other countries. In order to gain more public support, governments act as partners in healthcare projects (Alonge, 2017).

As an example to illustrate the above, we can consider Rwanda, which approved regulations on drones in 2016. This regulation made commercial drone delivery services for medical supplies possible (Toor, 2016). Consequently, drone delivery services have provided access to life-saving treatments. The U.S. company Zipline has partnered with the Rwandan government to develop commercial drone delivery services for medical supplies to hospitals located in remote areas. It delivers blood products such as red blood cells, platelets, and plasma (Baker, 2017). The project was launched in 2016. By September 2019, more than 13,000 deliveries of blood products had been made (Coulibaly, 2019).

Another obstacle that impedes developing countries 'healthcare digitization is that their workforce lacked preparedness to benefit from digital health (Tran Ngoc et al., 2018). For instance, hiring and retaining digital health professionals is a significant challenge in Tanzania (Labrique et al., 2018; PATH, 2020). Some organizations are taking actions to reduce the shortage of digital workforce required for the healthcare sector. For instance, the Pulse Lab Uganda organizes annual workshops and other activities to train the data analysts (Alonge, 2017).

A further challenge that needs to be highlighted is that digital health projects in developing countries often fail to move beyond the pilot stage. For instance, the African digital healthcare landscape arguably suffers from too many pilot projects (Tran Ngoc et al., 2018). A potential solution would involve scaling up the digital healthcare pilot projects that have been on-going rather than starting up new pilot projects. Tanzania's electronic Tool to Improve Quality in Health (e-TIQH) represents an example of a successful scale-up of digital health projects. This program is being implemented to address the challenge of insufficient access to quality healthcare in the country. The goal is to improve health system managers' supervision of health workers and provide real-time performance feedback to them (The Novartis Foundation, 2020). A similar program was launched in Mali (Labrique et al., 2018). Moreover, encouraging eTIQH results from one country convinced the other country to take further initiatives to establish programs directed at supporting eTIQH (Labrique et al., 2018). A combination of top-down and bottom-up approaches was employed for reaching scale. At the top level, government strategies are being implemented to build a strong culture of data collection. Senior government officials are supporting a culture of data use. They have made it a priority to intensify data use to improve the management and accountability of health system performance (PATH, 2020). It has led to the development of good data systems and the integration of information produced from such systems. Health workers have been trained in data systems /and data use (PATH, 2020). All these facilitated a bottom-up approach to development, integration and governance of data and data systems (PATH, 2020)

3.7. mHealth

As a subset of digital health that was examined by Stephanie and Sharma (2020) in this special issue, mHealth technologies are diffusing rapidly. For instance, Zion Market Research (2019) estimated that the mHealth apps market will be more than 111 billion by 2025. mHealth involves delivering healthcare services and information via mobile technologies (Arie, 2015; Hsu et al., 2016; Ryu, 2012). Prior researchers have identified five types of mHealth technologies (Bhavnani, Narula, & Sengupta, 2016; Walsh, Topol, & Steinhubl, 2014). They include: a) smartphone health apps such as Apple iPhone Health, Azumio's Argus and Samsung Galaxy SHealth; b) smartphone-connected medical devices such asglucometers and pulse oximeters; c) wearables and wireless devices such as fitness bands and smartwatches; d) handheld-imaging platforms such as the pocket-sized ultrasound Vscan developed by GE Healthcare; e) miniaturized sensor-based solutions such as Automation Healthcare System (AHS), which facilitates information sharing between doctors and patients through IoT (Velrani & Geetha, 2016).

An encouraging trend from the standpoint of mHealth technology in developing countries is that cellphones are becoming pervasive in these countries. According to the International Telecommunications Union (ITU), developing countries had a cellphone penetration rate of 102.8 % in 201. Even in least developed countries (LDCs), which are low-income countries that perform poorly in human assets and face high economic vulnerability, 72.4 % of the population used cellphones. Unsurprisingly mHealth apps are being widely used in these economies. For instance, according to the GSM Association, Africa had 202 active mHealth services in 2017 (Owings, 2019).

3.8. Globalization of digital health technologies

The processes driving the globalization of technologies (Archibugi & Michie, 1997; Iammarino & Michie, 1998) have also affected the digital health sector. Multinational Corporations (MNCs) are increasingly generating innovations across more than one country (Iammarino & Michie, 1998). Many Western MNCs are generating digital health innovations in developing countries. For instance, IBM Research Africa is developing AI applications to determine the best ways to fight malaria. It also applies game theory and deep learning data analytics to diagnose pathological diseases cancer, and cardiovascular diseases. and birth asphyxia (Ndung'u & Signé, 2020).

Another process is the collaboration among public and business institutions (Archibugi & Michie, 1997; Iammarino & Michie, 1998). For instance, GE has teamed up with Tanzanian health research organization Ifakara Health Institute to provide Tanzanian healthcare workers with portable ultrasound devices. Midwives and nurses in rural areas use them to assess the wellbeing of pregnant women (The Medical Futurist, 2018).

3.9. Generation of digital health-related innovations locally

Some developing countries have also been successful in generating advanced digital innovations in healthcare. For instance, Medical professionals in Ethiopia are using AI to correctly diagnose serious medical diseases such as cancer (Champlin, 2017). Likewise, Nigeria's Ubenwa has developed an AI system to analyzes a baby's cries to predict asphyxia, which is the third-highest cause of infant mortality (Spector & Daga, 2008. In a trial with 1400 pre-recorded baby cries, the solution was reported to have a 95 % accuracy in its predictions (Okunola, 2018).

In China, Ping An's Good Doctor project aims to provide a one-stop healthcare ecosystem platform. In 2018 the company launched a miniature clinic called "One-minute Clinics" as a pilot project in Wuzhen near Shanghai. The unstaffed clinics employ AI to connect patients with Ping An Good Doctor's specialist consultant. The AI Doctor gathers the patient's medical information and determines a diagnosis plan. The system's plan is to include a smart medicine cabinet with 100 common medications for patients to get their medication after the diagnosis (Lovett, 2018. In early 2019, the company expanded the projects in the country's 8 provinces and cities. By that time, Ping Anhad signed service contracts for about 1,000 units, that would deliver healthcare services to over 3 million users The Medical Futurist, 2019).

4. South-South and South-North collaborations

Most of the software, hardware and infrastructure related to mHealth originate from developed countries, also known as the global North (Curioso & Mechael, 2010). However, this paradigm is being challenged. A number of initiatives to maximize the benefits of digital health in developing economies have led to an increasing emphasis and focus on South-South and South-North collaborations. A highly visible example is the mHealth Alliance, which was formed in 2009 by the United Nations, the Rockefeller Foundation, and the Vodafone Foundation. The goal was to maximize the benefits of eHealth in developing nations (Curioso & Mechael, 2010). As of 2014, mHealth Alliance members included 300 organizations from 59 countries, which assisted digital health projects in 14 developing countries, such as Ghana, India, Kenya, Malawi, Nigeria, Senegal, South Africa, Tanzania, Uganda and Vietnam (Makoni, 2014).

5. Implications for future research

The issues discussed in this special issue also raise many questions that present an opportunity for future investigation. Stephanie and Sharma (2020) covered issues of emerging information technologies in healthcare. Blockchain is viewed as a promising emerging technology that is expected to fundamentally alter the practice of healthcare (Kshetri, 2018; Sharma et al., 2020). An intriguing future research avenue is to examine the deployment of blockchain in healthcare. In-depth case studies of blockchain in healthcare can uncover some of the key benefits of this approach as well as challenges faced in implementing it.

Yet another future research area is the evolving regulatory context for digital health. For instance, in 2016, the Chinese government enacted a new law that banned the use of third party mHealth apps in making appointments with doctors. The law required patients to make appointments directly through the hospital. Since most Chinese hospitals are public organizations, the intention behind the new law was to discourage third-party companies to benefit from public resources (Hsu et al., 2016). Likewise, the U.S. Food and Drug Administration (FDA) has issued guidance clarifying the agency's regulation of digital health products (FDA, 2019). An intriguing avenue for future research is thus to examine how issues around digital health are constructed, responded to, regulated and policed in countries across the world.

A number of future research directions in the area of mHealth technologies could be fruitful for the attainment of health-related Sustainable Development Goals. Prior research has suggested that healthcare is a key area that is likely to be transformed by the fifth-generation (5G) cellular network (Kshetri, 2019). A possible area of future research might be to look at the influence of 5G networks on mHealth applications.

We noted above that mHealth apps are diffusion rapidly in developing economies. However, to date, no systematic study of these apps has been conducted. We call for future research in which scholars could attempt to examine how successful and unsuccessful different mHealth apps used in these countries might be in delivering healthcare services.

AI is another emerging technology that has captured the attention and imagination of many scholars and practitioners (Jiang, Jiang, & Zhi, 2017; Strickland, 2019). It is not yet clear whether AI in healthcare is only hype or it will become a reality. Future research on this important topic should help us better understand the phenomenon of AI in healthcare that is becoming pervasive and ubiquitous.

The above discussion makes it clear that digital health to advance health services delivery in developing countries is far from fully utilized (Tran Ngoc et al., 2018). We identified several barriers and obstacles to digital health in these countries. In future research, scholars should investigate more deeply how governments and non-governmental actors can take measures to address these various barriers and challenges. Specifically, case studies of successful digital health projects such as e-TIQH in Tanzania and Mali can provide insight into how various barriers were overcome.

6. Concluding remarks

Digital health is undergoing transformation that is consistent with the 4th industrial revolution (4IR). Among the more encouraging developments is the diffusion of digital health systems into developing countries (Alonge, 2017; Arie, 2015; Kshetri, 2016; Labrique et al., 2018). Key factors that have facilitated the development and implementation of such systems in these countries have been discussed in this introduction. For instance, due primarily to the rapid diffusion of cellphones. This, in turn, provides opportunities for innovation, growth and development, much like what Grameen Banking did for social enterprise and empowerment of women in Bangladesh. Such a trend could serve as a backdrop for whether the benefits pervasive

5G networks, devices and apps could outweigh perceived costs in order to promote adoption of m-health (Dwivedi et al., 2016).

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