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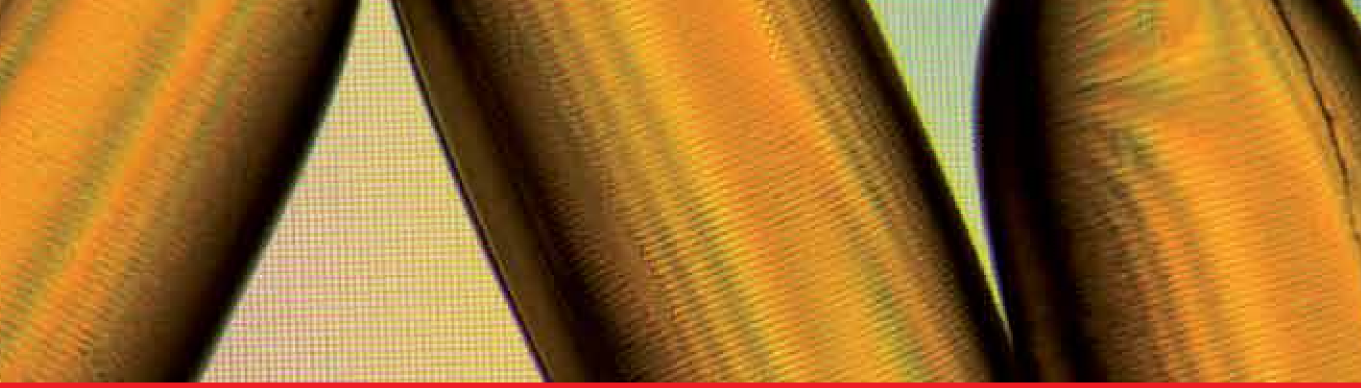
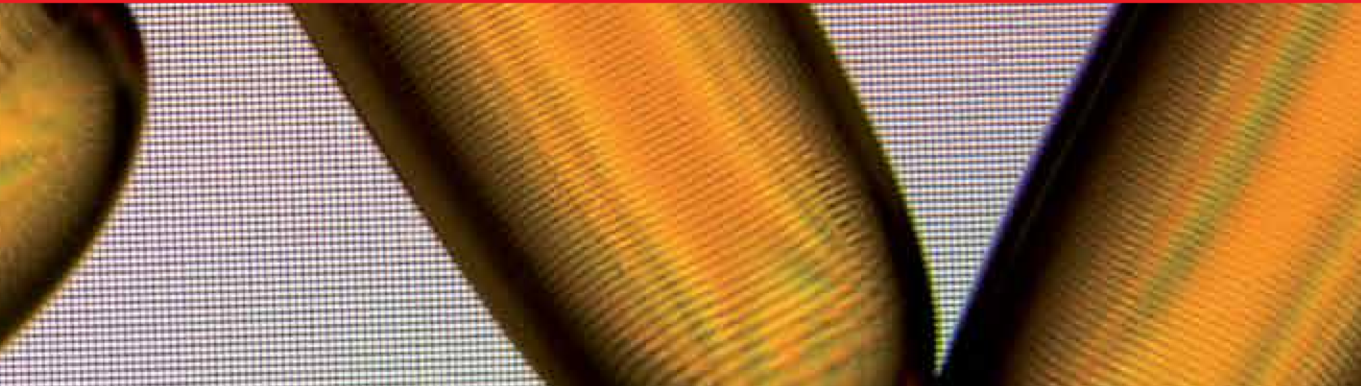


Smart Healthcare

Edited by Thomas F. Heston



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Edited by Thomas F. Heston

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Meet the editor

Thomas F Heston MD MSc FAAFP FASNC FACNM is a Clinical Associate Professor at the Elson S Floyd College of Medicine in Spokane, Washington USA. He has been involved in the development of artificial intelligence in health care since the 1990s when, as a nuclear medicine resident, he researched the application of neural networks in renal transplant medicine. He has subsequently been involved in the development of picture archiving and communication systems, online learning programs, and smart phone apps. Previously as an Assistant Professor (adjunct) at Johns Hopkins, he established the first PET/CT program in the United Arab Emirates Cancer Center in Al Ain. His current research focus is on the application of blockchain technology to health care.

Contents

Preface

This first edition of *Smart Medicine* provides readers with an introduction to smart medicine, which is the application of technology to the health care system. Smart systems require not only advanced hardware technology, but also intelligent algorithms that learn over time. Today, the advances made in hardware have enabled the response times to patient data to become clinically useful. This has allowed the development of artificial intelligence to gain increasing utility in the real time management of patients. The advances in data storage, internet connectivity, and processing speed have resulted in large databases that are being used to identify new patterns in human physiology and DNA. The analysis of big data is a fruitful area for medical researchers for decades to come.

Improvements in medical software are not only important in medical record keeping, but can help guide medical decision making and speed up response times to changes in patient conditions. This book on smart medicine provides the reader with an overview of current thinking in the field. Advances in pharmaceuticals and surgical techniques have greatly advanced medicine in the past. Now with the improvements in data transmission speeds, data storage, and processor speeds, advances in software and artificial intelligence have the potential to once again lead to a medical revolution. Smart medicine will lead this progress in human health and the practice of medicine.

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Chapter 1

Introductory Chapter: Blockchain Technology and Smart Healthcare

Thomas F. Heston

1. Introduction

Phase 1 of the technology revolution began with the development of the computer and the computer chip. Phase 2 occurred when communication between computers became widely distributed via the Internet. We are now in phase 3 which is the development of artificial intelligence to replace or augment human intelligence. This revolution in technology has and will continue to have profound effects upon healthcare, human health, and longevity.

Blockchain technology has played a major role in the ongoing development of artificial intelligence. In the financial world, it has created a new, Internet-based global monetary system through the development of the Bitcoin protocol [1]. The ethereum blockchain has made the use of Turing complete computer programs available online, enabling the development of smart contracts [2, 3]. To complete the transition to a smart economy, the blockchain-based, self-sovereign smart identities are being developed [4, 5]. Taken together, these blockchain-based developments have created the foundation for a truly decentralized healthcare system in which patients have control of their own medical data by the use of a digital identity, and providers are reimbursed with digital money (bitcoin) immediately after providing documentation of services rendered (via ethereum-based smart contracts).

While promising, blockchain technology remains in its infancy, and there continues to be a need to clarify what exactly blockchain technology involves. To do this, a review of the original Bitcoin white paper is required. This white paper was published under the pseudonym "Satoshi Nakamoto." It is unknown whether this pseudonym represents a single person or group of people, as the author as of 2019 remains unknown. The original Bitcoin codebase and white paper were written in 2008 [1, 6]. The first bitcoin was mined by Satoshi Nakamoto on January 3, 2008, and the first bitcoin transaction occurred shortly thereafter between Satoshi Nakamoto and Hal Finney [7].

The blockchain is simply a distributed database that is populated with transactions. Given the nature of distributed blockchain databases, the transactions are immutable and permanent. Furthermore, advanced computer cryptography has made it possible to fully anonymize transactions using zero-knowledge proofs [8]. The transactions recorded can be many different things, including financial transactions using bitcoin, smart contracts using ethereum, Internet advertisements [9], or any of a number of healthcare-specific transactions. The immutable, permanent nature of blockchains makes healthcare applications particularly useful in maintaining patient records, billing insurances, and conducting medical research [10].

The revolutionary aspect of blockchain technology is that it eliminates the need for a trusted third party to validate transactions and store data. With current electronic medical records, for example, access to medical records is controlled by the clinic or hospital. Individuals must ask the hospital for access to their own medical records. Medical records are stored by the hospital in a centralized location. This centralization of data storage creates a single point of entry for hackers [11].

Distributed blockchain databases, on the other hand, do not have a single vulnerable point of access, making them extremely resistant to malicious manipulation. For example, although Internet sites managing bitcoin have been hacked, the bitcoin blockchain has not. This is in spite of a $125 billion USD market capitalization. Theoretically, a hacker able to break the bitcoin blockchain would have access to billions of dollars. In spite of this large financial incentive, after more than a decade of existence publicly on the Internet, the bitcoin blockchain remains intact.

Not only does blockchain technology enable storing data in an immutable, permanent way, it also can store contracts in a similar way. Such contracts can be "dumb" and simply record an agreement, or they can be "smart" and take action. For example, a smart contract could automatically release funds from an insurance company, payable directly to the provider, immediately when proper documentation of medical services rendered was uploaded to the blockchain. Such transactions are enabled by having a blockchain-based digital identity for patients, digital assets for insurance company payments, and digital smart contracts. An integrated blockchain including all three of these components is NEO, originally founded in China, which aims to create the essential components of blockchain-based economy [12, 13].

Smart contracts, along with digital identities, enable the implementation of artificial intelligence in remote patient monitoring, hospital wards, and clinics. A smart contract could simply be the instruction to notify a patient's provider and/or possibly emergency medical services when the patient's wearable technology identifies new onset atrial fibrillation. The use of blockchain technology as opposed to a centralized database helps ensure data integrity, patient privacy, and database robustness.

By making artificial intelligence patient centric, blockchain technology is leading the way through the growing wave of technology and artificial intelligence. By creating self-sovereign digital identities, people will have control over their identification instead of relying on government institutions for identification. This is critically important, especially for refugees and the homeless. By creating several methods of transferring assets, blockchain technology allows people to trade directly with each other, without relying on a central bank or credit card company to audit their every transaction. Such monetary systems are essential for the creation of efficient smart contracts that do not rely excessively on a centralized verification process. Finally, blockchain-based smart contracts have the ability to efficiently analyze patient data and act quickly on the results.

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Chapter 2

Not-So-Smart Technology

Tulio Pereira dos Santos Maximo

Abstract

It is certain that smart technologies can benefit healthcare from an individual level to comprehensive healthcare services. This chapter reflects on the use of technologies in public healthcare systems and reveals some barriers encountered in the attempt to integrate the World Health Organisation wheelchair services' good practices into the Brazilian National Health Service information system. Between countries with a population larger than 100 million inhabitants, Brazil is the only to declare healthcare as a duty of the State and a civil right, providing free of charge services to its population. The service is moving from a fragmented to an integrated healthcare service on which the use of technologies plays an important role. This study shows the value of understanding the requirements of the different healthcare service stakeholders and considers the contextual factors to improve service quality. It also shows how technology can become a hurdle rather than assistance to improve healthcare provision.

Keywords: assistive technology, wheelchair service, Sistema Único de Saúde, electronic system, integrated healthcare system, participatory design, World Health Organisation, good practices

1. Introduction

For a long period in Brazil history, the care of the disabled population was neglected by the government and was provided mostly by the charitable institutions [1]. A turning point to this scenario was the creation of the national plan for the rights of the disabled people in year 2011. The Brazilian government plan consolidates a series of policies concerning social inclusion, access to education, accessibility and healthcare, the last of which declares the provision of wheelchairs free of cost for those in need [2].

It is a well-accepted fact in the literature that a wrong wheelchair specification can harm both the user and the caregiver and lead to the discontinuance of device use, resulting in wastage of time and resources committed to the wheelchair provision [3–6]. To confront these issues, the World Health Organisation (WHO) elaborated a series of good practices in the form of wheelchair service training material aiming the right wheelchair fit to the user characteristics [6–8]. Despite so, there was no evidence before the conduction of this study that the service provided in Brazil adheres to these guidelines or other wheelchair service good practices.

This chapter reviews the results of a study conducted in the wheelchair service provision in Belo Horizonte city, Brazil, with the aim to understand the functionality of these services in order to provide context-specific interventions and recommendations to improve the design of current services. This chapter emphasises how technologies have been used to collect user information and support informed decisions in the wheelchair service provided at Belo Horizonte city's National Health Service. The study compared the information collected to existing good practices and proposed interventions to promote the WHO's suggested good practices.

2. The complexity of brazilian healthcare services

Between countries with a population larger than 100 million inhabitants, Brazil is the only to declare healthcare as a duty of the State and a civil right, providing free of charge services to its population [9]. Public healthcare provision in Brazil occurs by a complex range of system and subsystems that includes public and private care. The Brazilian National Health service called Serviço Único de Saude (SUS) integrates services between municipalities, states, and the union to the philanthropic and for-profit services. The SUS is the only health service choice for more than three-quarters of the Brazilian population, serving more than 150 million people [9, 10]. With such a large and diverse population using a service that involves many institutions, managing user information represents a vital role for the well-functioning of the service.

The Brazilian healthcare service SUS is organised to operate similarly throughout the country. Despite great centralisation of SUS management under the union responsibility in the past, the focus has shifted to its decentralisation with emphases in its municipality level [11]. Consequently, it became more important to understand the municipality context in order to investigate its current issues and provide context-specific interventions.

This study focused on SUS services provided in Belo Horizonte city. The city is the capital of Minas Gerais state and represents a complex and unequal space that needs to be understood [12].

3. The move towards an integrated healthcare system

In a seminal book from the *Organização Panamericana de Sáude*—a regional WHO organisation—Mendes [13] reviews the existing healthcare systems and calls the attention for the move from fragmented to integrated healthcare systems. He explains that fragmented systems tend to focus on the health conditions and acute events and are heavily dependent on clinicians and nurses. On the other hand, the integrated systems have a balanced focus between acute and chronic conditions and stand on a multidisciplinary team. Mendes reinforces the trend in healthcare systems to move from fragmented to integrated systems, resulting in an increased role of multidisciplinary primary care teams in the coordination of the user care.

From the advancements made in Brazil towards a more integrated system, Mendes mentions the creation of health centres in the 1960s, the programme *Ações Integrada de Saúde* (suggested translation: Integrated Health Action programme) created in the 1980s, and the ongoing *Programa Saúde da Familia* (PSF, suggested translation: Family Health Programme).

Another strategy added towards an integrated health system was the *Estratégia de Sáúde da Família* (suggested translation: Family Health Strategies); the aim of which is to restructure the primary care in SUS employing the *Equipe de Sáude da Família* (ESF, suggested translation: Family Health Team). ESF is a multidisciplinary team supporting the primary care units formed by a minimum of one general practitioner or specialist in family health, one general nurse, one nurse technician and one community health agent [14]. To consolidate the multidisciplinarity of the primary care, the government created in 2008 the *Núcleo de Apoio à Saúde da Família* (NASF, suggested translation: Health Family Support Team) increasing the service offer and access and providing a bridge between primary and secondary care [15]. Each NASF team is composed of up to 19 professionals from a diverse clinical proficiencies providing support among 8–20 ESF teams. NASF personnel vary from physiotherapist, phonoaudiologist, social worker, acupuncturist, nutritionist, and psychologist, to cite a few examples. The purpose was to provide multidisciplinary care by fostering discussion of clinical cases, assessing users in its home environment, operating in the prevention and health promotion, supporting therapeutic projects and qualifying and increasing health interventions [16].

4. The wheelchair service functioning

The functioning of the SUS requires that user information flow between primary, secondary and other levels of care. It means that information is collected and shared between the ESF team, NASF team and other institutions related to additional levels of care.

The primary care team from ESF and NASF first identifies in the community the user in need of a wheelchair or other assistive technologies provided by the SUS. These users are then referred to the secondary level of care. In Belo Horizonte city, assistive technology services, such as the wheelchair service, are provided at SUS level by the CReabs (short for rehabilitation centres). Hence, information flow related to the wheelchair service occurs mainly between the staff from ESF, NASF, CReab and the wheelchair suppliers (**Figure 1**).

The services vary according to the type of wheelchair offered, classified internally into two different categories: standard wheelchairs and adapted wheelchairs.

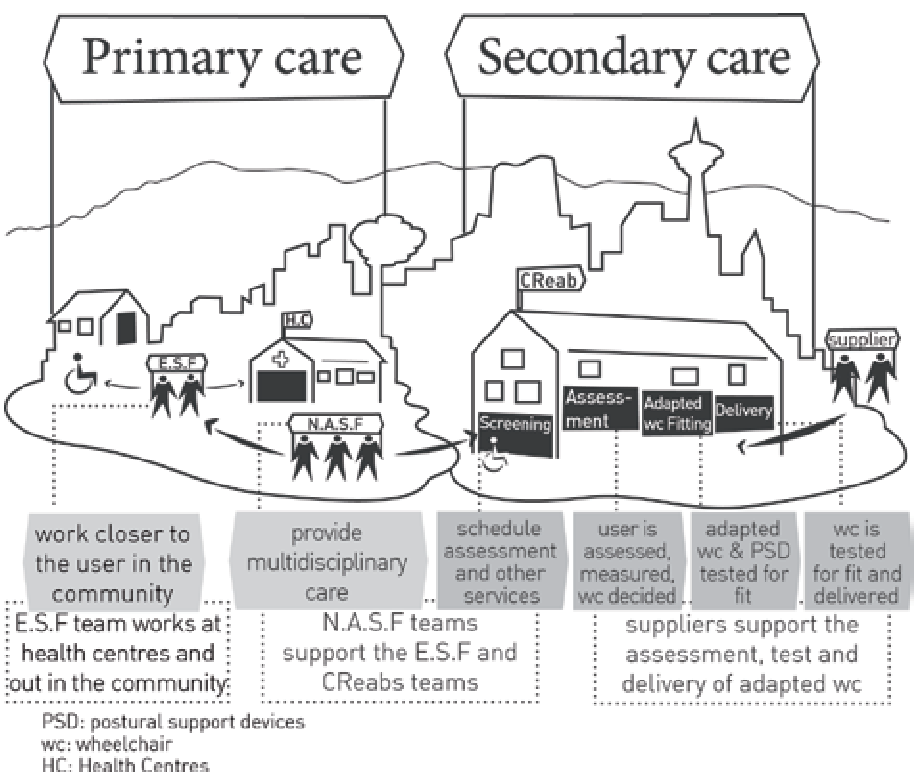

Figure 1.
Healthcare teams and stages involved in Belo Horizonte wheelchair provision.

The first two service stages are common to all wheelchair users, which are the *screening* and the *assessment stage*.

The *screening stage* is the entrance door for all CReab service users (**Figure 1**). In this stage, users provide their referral to the CReab staff who shortly assesses their overall requirements, often beyond the referral area. The outcome is scheduling the users to the available services including services provided by third-party institutions. The users in need of a wheelchair are scheduled for an *assessment stage* at CReabs.

At the *assessment stage*, the CReab staff assess the user, take their measurements and decide if the required wheelchair is standard or adapted. If an option is made for a standard wheelchair, the model and specification are agreed with the user, and

Stage		Activity	How information is recorded
Primary Care		CReab service or assistive technology device is prescribed	Referral form *Solicitação de OPMAL*
Secondary Care (at CReab)	Screening	User is referred to a rehabilitation service	Referral form *Soliticação de tratamento fisioterátpico* AND **Electronic System** *SISREG*
		User is referred to assessment stage	Assessment waiting list spreadsheet*
		User needs to return to the referring institution	Counter referral form *Guia de contra referência*
	Assessment (CReab staff)	Interview with the user	**Electronic System** *SISREDE*, or Form *Ficha de Evolução Manual*
		Measure the user	Form *Dimensões Básicas do Cliente**
		Specify the wheelchair characteristics	Form *Especificação da Cadeira de Sistema Postural**
		Authorize the wheelchair purchase	Authorization report
	Assessment with supplier	CReab staff interview the user	**Electronic System** *SISREDE*, or Form *Ficha de Evolução Manual*
		Supplier interview the user	Form vary according to supplier
		Supplier staff measure the user	"
		CReab and/or supplier staff specify wc characteristics	"
		CReab Staff authorize the Wheelchair purchase	Authorization report
	Wheelchair fitting	CReab staff accompany the supplier	**Electronic System** *SISREDE* *or* Form *Ficha de Evolução Manual*
	Delivery	CReab and/or supplier staff test wheelchair fit	**Electronic System** *SISREDE or* Form *Ficha de Evolução Manual*
		User sign the receiving of the wheelchair	Authorization report

* Name and form vary slightly between CReab

Table 1.
Electronic systems and printed forms used to collect user information.

the wheelchair purchase is authorised (**Table 1**). If a decision is made for an adapted wheelchair, the user is scheduled for another assessment with the selected supplier staff in conjunction with CReab staff.

One additional stage may be required for users in need of an adapted wheelchair after the assessment with the supplier. Often bespoke adjustments are expected to accommodate the user deformities or specific requirements such as structure to accommodate ventilator or other devices. During the *adapted wheelchair fitting stage*, the supplier staff in conjunction with CReab staff fit the users in a partially made wheelchair to determine the required postural support devices (PSDs) and other bespoke modifications.

The service cycle is completed after the *delivery stage* (**Figure 1**). At this stage, the user is assessed for the wheelchair fit. If no problems are encountered and the wheelchair fit the user as expected, he or she receives the service guarantee and signs the delivery of the wheelchair, concluding the service cycle. Nonetheless, if the user, the supplier or the CReab staff identify any issue with the wheelchair fit or any other problem with the wheelchair, a decision is required. This can vary from a simple on-spot adjustment to the replacement of the wheelchair model and restart of the entire service cycle.

5. The existing technologies

In order to deal with the multilayer complexity of the wheelchair service in Belo Horizonte SUS, two electronic systems are employed. The *Sistema de Informação de Regulação das Ações de Saúde* (SISREG) is one of them. SISREG was created to be used in the entire country to coordinate the request for hospital and outpatient services. SISREG intends to speed up the population access to health services by exchanging information between regional health units through the Internet. The other system used is the *Sistema Sáude em Rede* (SISREDE). The SISREDE is a local-level intranet system implemented by the Belo Horizonte Municipal Department of Health aiming to integrate and manage user information.

In addition to the electronic systems, a series of digital and printed files such as referral forms and an authorisation report are used to collect user information and record service procedures (**Table 1**). The printed forms specific to the wheelchair service are made available to the practitioners directly involved in the service and kept in a physical folder. This folder also contains information and photos about the wheelchairs supplied.

6. Current issues

The SISREDE system was developed based on the concept of business intelligence (BI), which refers to technologies, applications and practices for the collection, integration, analysis and presentation of business information [17]. The purpose of BI is to support better business decision-making. Though the SISREDE enables recording and reassessing user information as well as producing reports, it does not guarantee the quality of the healthcare information recorded neither promotes service quality on a general scale. For that, information collected should comply with evidence-based practice and existing healthcare and service delivery system good practices. The SISREDE system does enable the incorporation of such good practices as it was designed to permit personalised healthcare assessment. However, the study found that the system was yet adapted to comply with existing good practices in assistive technology services and did not reflect the requirements of many key stakeholders.

Currently, the SISREDE only requires the collection of elementary information about the user, its health condition and its environment. The study revealed there was no consensus between CReabs staff regarding how to conduct the activities involved in the various service stages. There was no use of an evidence-based protocol to ensure that the necessary areas were covered when assessing the users or fitting the wheelchair to them. There was no clear agreement about what kind of information should be passed or who should pass them. Many users ended up not being informed concerning various topics. Therefore, the recurrence of similar information passed to users was considerably low. Also, duplicated information was collected by different staff in different stages whether important information was not being collected thoroughly. The study concluded that the information collected proved not enough to comply with existing good practices in wheelchair services. Many gaps were found regarding the service good practices suggested by the WHO [6–8] and the Association for the Advancement of Assistive Technology in Europe (AAATE) [18]. These are exposed in **Figure 2** by means of a Swiss cheese model for cumulative effects. The model is used to identify cumulative failures in various stages of a process or complex system that can lead to accidents, often applied to identify the causes of accidents on mass transportation systems and to improve healthcare systems. The holes represent current failures and latent conditions. An adverse outcome occurs when the holes in various layers line up to permit a trajectory, allowing an accident to occur [19]. In this case, the accident was interpreted as the risk of the wheelchair not fitting the user profile.

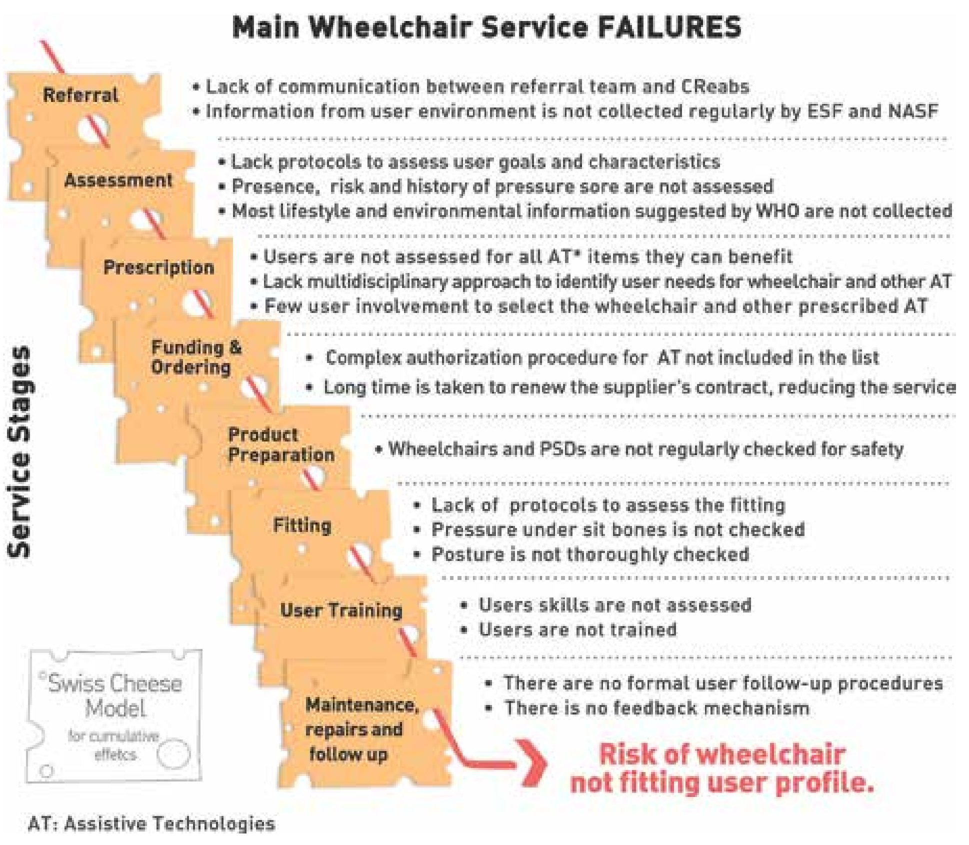

Figure 2.
Main failures to apply the wheelchair service good practices.

7. Overcoming barriers through participatory design

To improve service quality and promote wheelchair service good practices, the researcher adopted a participatory approach to understand contextual barriers and engage the service stakeholders in the design of a series of interventions. During 3 months, service providers were observed on a variety of wheelchair service procedures (n = 153) to understand how user information was collected and used in comparison to existing good practices. After observations, semi-structured interviews (n = 12) and a follow-up survey (n = 11) were conducted with service stakeholders to understand the applicability of existing good practices and design the interventions. The intervention consisted of a set of forms and a checklist based on the WHO wheelchair service training package [7, 8]. The intervention contained:

- A referral form
- An entry-level form to collect information about the user environment
- A measurement tape to be given to the user with which to collect raw data
- An assessment form
- A wheelchair fitting checklist
- A leaflet for the user about pressure sore prevention and care.

The interventions were tested in 95 service procedures, by the end of which a copy of the suggested forms and checklists tested were collected. Follow-up interviews were conducted with practitioners using the suggested forms and checklists (n = 17) to understand the barriers encountered and how to improve the forms and checklist to the service context. Follow-up interviews were also conducted with service managers and administrators (n = 9) to investigate possible ways to mitigate the barriers encountered and meet the different stakeholders' requirements. Key stakeholders identified were the wheelchair user and its caregivers, healthcare practitioners from CReab and suppliers, administrative staff from CReabs and management staff from CReab, suppliers and Belo Horizonte Municipal Department of Health. The intervention tested was modified and presented to each CReab centre. On the opportunity, an executive summary was delivered to service managers containing a summary of the research findings, the updated protocols and suggestions on feasible implementation guidelines.

8. Not just the right for a wheelchair but the right wheelchair

Initially, many practitioners recommended that the information collected in the suggested interventions should be added to the SISREDE to guarantee that every care comply with good practices. Nonetheless, the bureaucracy to suggest changes in the SISREDE system proved to be a huge barrier, and it was not possible to pilot it during the study. Instead, two types of files were made available to CReab practitioners when testing the protocols suggested in the intervention: digital interactive fillable forms in pdf format and printed forms.

Some participants from the screening stage showed signs of resistance to test the interventions designed for this stage, suggesting that they required more time and training. CReab coordinators noticed that this resistance occurred mostly between participants that had not been involved in the early studies or did not engage in the study presentations, proving the importance to engage as many practitioners as possible from the early stages of interventions. A critical suggestion from participants using the interventions for the screening was to clarify how service users can accurately gather information from their environment in order to bring to the assessment stage.

Interventions designed for the assessment stage, the assessment form, were well received by all participants. Even though there was a minor increase of 2–5 minutes in the average time spent when using the assessment form, the increase did not reach statistical significance (as $P > 0.5$) [20]. It called the attention that most participants did not complete the form sections related to the presence, risk or history of pressure sores even though the cushion to relieve the pressure was one of the latest items included in the list of devices offered by the SUS. The reasons are likely related to other findings such as the lack of staff training to assess the users' pressure sores and the lack of criteria to prescribe the pressure relief cushions. As a result, there was no prescription of cushions to relieve pressure within the study observations.

There were various modifications to the assessment form. A key modification was including the assessment of other assistive technologies provided by the SUS that are directly involved with the wheelchair use such as activity table, transfer board and cushion to relieve the pressure.

Although no resistance was encountered to use the proposed wheelchair fitting checklist, the CReab participants did not check the pressure under the user seat bones, an activity suggested in the form. The main modification to the fitting checklist was inserting an observation entry field at the end of each section to accommodate practitioners' notes observed to support informed decisions.

It was recognised that training is necessary to formally implement the protocols in the service and overcome existing barriers. Most of the suggested trainings can be achieved using the resources from the WHO wheelchair service training package basic level [7], available in Portuguese language.

When interviewed after testing the interventions, practitioners were asked again about adding the forms and intervention to the SISREDE system. Many have changed their mind not to add it to the system stating that it would only add one more step as they would have to print the forms to attach to each user archive. Another point raised was the system's lack of stability. Many practitioners were observed taking hand notes or using a word processing software before transferring their notes to the SISREDE system, afraid to lose their assessment annotations.

9. The future of SUS and the use of smart technologies

Although Brazilians have access to free of charge public healthcare services, there is still a long way to improve service quality in order to comply with existing good practices.

Restricted funding is certainly a crucial concern in stopping SUS development. Reports indicate that the private healthcare sector invests more than the government, although the SUS is the main source of care for nearly three-quarters of the Brazilian population [21]. Besides, the government healthcare expenditure per year with each citizen has been way below the world's average rate [21]. Also, there is a limited resource of around 24.5 million Brazilian reais—approximately 6.6 million US dollars at quotation in 17/01/2019—for the annual costs regarding the assistive technologies procedures at the SUS [22]. During this study, the suppliers' participants often complained about the low price paid on most assistive technologies, only updated once in 7 years while Brazil inflation had grown drastically in recent years. The consumer price index used to measure country inflation was 6.4% in 2014 and 10.6% in 2015 when the study was conducted [23]. With healthcare investments frozen from 2017 to 2037, there is no indication that the situation will improve but actually will worsen as the population relying on the SUS has been growing as a consequence of the financial crises lived in Brazil [24]. On top of that, there is still the danger for current social advancements and programmes to be discontinued or started from scratch whenever a new political party assumes the power [25, 26]. It is difficult to believe that the quality of the service can significantly improve without increasing the budget not only for the assistive technology procedures but for the SUS service overall.

The current financial restrictions only emphasise the importance to make better use of the existing electronic system to promote service quality. Considering that the current electronic system can incorporate existing healthcare protocols and good practices, more effort should be put to alleviate the bureaucracy involved in improving the system. Modification should consider not only practitioners' personal requirements but also the integration between the needs of different service stakeholders. Users in need of assistive technologies should be assessed for the entirety of assistive solutions required or at least for those provided by the service. Also, the system should be more reliable, so it can record procedures without having to require the staff to take additional notes or print the information collected.

The research proved a great interest from practitioners to implement existing good practices. The primary barrier to improving the service quality on their own is the lack of time due to service queue and difficulty in accessing information. Participants complained that academic institutions researching the SUS hardly ever return to the service to share the results, provide recommendations or engage in service improvement. One result illustrates the need for more conversation between academic institutions and local healthcare. Brazilian government created in 2010 an open university network for the SUS' practitioners to deal with the lack of training and lack of access to information. The platform includes four modules related to assistive technology provision with 30 hours course load each [27]. However, only two CReab participants reported enrolling any of the modules offered even though the course was developed by a federal university located in Belo Horizonte [28]. Future research and public policies should address this gap and encourage academic institutions to be more engaged in local healthcare service provision, helping to identify issues and not only providing care solutions to its community but also helping to implement them.

It appears that in order to provide better quality service, public healthcare in Brazil may have to rely on 'not-so-smart technologies' for a while.

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Conflict of interest

I hereby declare that I have no affiliations with or involvement in any organisation or entity with any financial interest or nonfinancial interest in the subject matter or materials discussed in this manuscript.

Appendices and nomenclature

AAATE	Association for the Advancement of Assistive Technology in Europe
BI	business intelligence
CReab	Centro de rehabilitação
ESF	Equipe de Sáude da Família
NASF	Núcleo de Apoio à Saúde da Família
OPMAL	Órteses, próteses e meios auxiliares de locomoção
PSD	postural support devices
PSF	Programa Saúde da Familia
SISREDE	Sistema Saúde em Rede
SISREG	Sistema de Informação de Regulação das Ações de Saúde
SUS	Sistema Único de Saúde
WC	wheelchair
WHO	World Health Organisation
WSTP	Wheelchair Service Training Package

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Chapter 3

Smart Tracking and Wearables: Techniques in Gait Analysis and Movement in Pathological Aging

Beatriz Muñoz, Jaime Valderrama, Jorge Orozco, Yor Castaño, Linda Montilla, Domiciano Rincon and Andres Navarro

Abstract

In this chapter, we describe the aging process and, more specifically, the pathological aging, associated with neurodegenerative diseases and its relation with gait. Then, we explain the importance of using quantitative gait analysis techniques using wearables and other technologies to diagnose different conditions that can be complex to discriminate using only the physician naked-eye diagnosis. We analyze different approaches used for gait analysis using wearables and affordable devices like inertial units (IMU), accelerometers, and depth cameras like Microsoft Kinect or Intel's RealSense, which have been available at least in an academic context but will be available for daily use in the near future.

Keywords: aging, Parkinson's disease, gait analysis

1. Aging

Aging of the population is one of the greatest current challenges because this implies a social transformation that includes work, economic, social protection, home, and coverage in health services. According to the data of World Population Prospects, the 2017 revision, it has been considered that most of the population has a life expectancy equal to or greater than 60 years, which is growing faster than the younger groups, and has estimated that by 2050, this group would increase globally to 2.1 billion, as well as 3.1 billion in 2100 [1].

1.1 Characteristics of aging

In the context of aging, physiological problems affect the brain. It has been considered that cognitive impairment and gait changes are the most significant since they have a high impact on the quality of life, so there is currently evidence in favor of neuroprotective strategies such as diet and exercise, especially in neurological diseases [2]. In recent years, it has increased the empirical evidence that suggests that the aging process could be delayed and, therefore, increase life expectancy accompanied by improvements in healthy lifestyle habits [3]. Likewise, advances in technological development have allowed the implementation of easy-to-use and adaptable devices to identify subtle markers of early symptoms that could be useful for designing intervention or stimulation programs in such a way as to positively influence the healthy aging process.

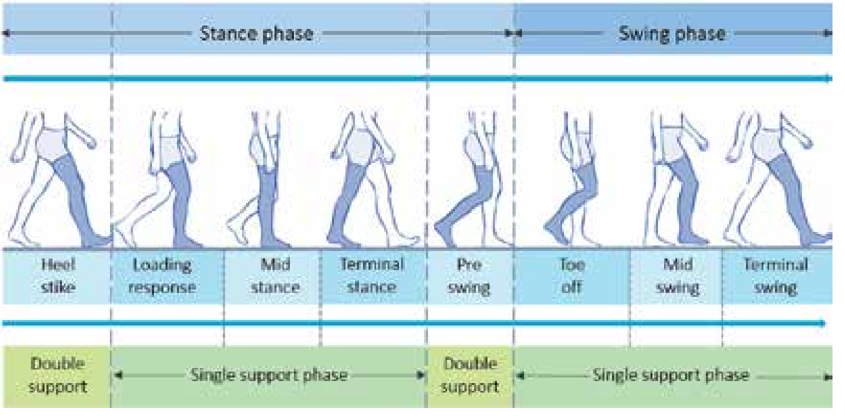

Figure 1.
Gait phases.

In advanced ages, a decline in sensorimotor functioning and control ensues. The causes of these deficits can be multifactorial and involve the central nervous system, sensory receptors, muscles, and peripheral nerves [4]. Falls are a frequent problem in the elderly population, and it has been determined that many of these occur in the context of walking. Older adults have less dynamic stability during walking due to the deterioration in the sensitivity of the body as well as the movement of the trunk in response to small disturbances that may occur during walking [5]. This deterioration in fine motor control, gait, and balance affects the ability of older adults to independently execute the activities of daily life which affects their autonomy and functionality. However, it is important to establish that gait and mobility are not the same thing. In gait, there is a bipedal activity in which the center of gravity moves forward and includes two components: (1) the locomotion as the ability to initiate and maintain the rhythmicity in the steps and (2) the balance that is the ability to maintain the balance and posture. On the other hand, mobility is the ability to displace in the environment with ease and without restriction. In adults, mobility is an important factor in the loss of functional independence. Walking is basic in human motion and can be studied by assessing the gait cycle. This cycle is described from the moment one foot strikes the ground until the same foot returns to the ground. The body displaces in space for specific distance and the cycle repeats. Components of the gait cycle include stride, distance covered from one-foot strike to striking the ground again; distance covered by each foot and it is symmetric in length for both sides. The frequency of stepping is called cadence, and it is described as the number of steps per minute (**Figure 1**).

1.2 Gait and aging

The neurophysiology of gait is a complex process that involves subcortical and cortical levels and executive aspects of attention and planning. Voluntary movements are always accompanied by postural control, which couples the programs that relate to the task with the adjustments of the movements and posture. The voluntary movement includes specific parts of the body, as well as adjustments of anticipation depending on the goal to be achieved. For the execution of the movements and the prediction of the postural programs, the cerebral cortex, the basal ganglia, the cerebellum, and the brainstem are used by descending systems that act on the spinal cord [6]. The signals from the basal ganglia and cerebellum control the excitability of the neurons in the cerebral cortex and brain stem by ascending and descending projections. All of these contributes to the planning, programming, and initiation of gait and, finally, modulates the rhythm and muscle tone during locomotion. It has been described that the loop formed by the basal ganglia, cerebellum, and the motor cortex can contribute to the purpose of the recalibration of the walking pattern to navigate in different environments [7]. The hierarchical organization of gait can also be described in several levels based on the classification of Hughlings Jackson [8]. The lower levels would be related to the cells of the anterior horns and the visual, vestibular, and proprioceptive system, which would be involved in the production of the force required for the balance and locomotion, as well as the sensory information, and would be associated with the orientation in the space in relation to the support surface. The middle level would modulate and refine the forces to stand, balance, and locomotion. Finally, the upper level would interpret and integrate the sensory input to select and organize the appropriate motor programs for the desired action [9].

The decrease in gait can predict a mild cognitive impairment suggesting that motor changes may appear earlier than cognitive deficits [10]. Variables such as speed would be considered the most sensitive measure in the older population and could be a common and final expression of the decline that may occur with aging even when there are no clinically significant alterations or subjective complaints in relation to gait and mobility.

Slowness in walking is associated with different factors, including risk factors such as high blood pressure (HBP), as well as changes in brain integrity age-related. Magnetic resonance (MR) studies in subjects without neurological disease have reported decreased volume in motor regions, the prefrontal cortex, the basal ganglia, and the medial temporal lobe. Among the structures described, the decrease in the right hippocampus, related to sensorimotor integration functions, as well as spatial memory, is strongly linked with cognitive deterioration profiles, as well as dementia. While speed could be considered useful in clinical screening, other studies indicate that it is also important to establish how gait parameters would be involved in aging since it has been reported that they could predict the risk of falls and loss in mobility affecting the quality of life [11]. The importance of these findings lies in the recognition of predictive factors that are easily accessible to clinicians who can detect early cognitive deterioration as well as dementia, which in turn will enable the creation of better strategies for planning, prevention, and treatment options [12].

As described above, the gait is multidimensional, and it is a challenge with age because it requires mechanisms of automaticity and cognitive control to maintain performance under different conditions and to mitigate the effects of age. A model of five domains has been proposed to understand the complexities of gait: step, rhythm, asymmetry, variability, and postural control to evaluate gait in older adults. Due to this, each character has different neural mechanisms involved. Within these domains, the pace, variability, and postural control were more sensitive when age was used as a criterion to discriminate the walking pattern. This could be related to cognitive control and the impact of executive commitment rather than the rhythm which is associated with circuits of the brainstem and the spinal cord [13]. In addition, speed has been the most used to evaluate, discriminate, and predict measurements throughout the life course since it has strong clinimetric properties [14].

Multiple factors contribute to maintaining the dynamics of gait; of these, the balance is considered a fundamental characteristic to achieve ambulation. Balance can be defined as the ability to control the body mass on a surface in order to maintain balance and orientation [15]. This process involves the integration of information from the nervous system, the sensory system, and the musculoskeletal system that allow the stabilization of the body mass during the activities of daily life [16]. The alteration of the balance in older adults is one of the most referred symptoms in the consultation, and when this is added to the gait alterations, they are considered predictors of falls [17]. It has been estimated that between 20 and 33% of adults over 65 experience balance problems; in addition to adults over 60, there is a 30% chance to fall at least in the first year, increasing by passing the 75 years [18].

2. Defining pathological aging: concepts from human locomotion

As previously described, gait depends on the integrity of the structures involved in both the planning—central nervous system—and the execution of motor tasks, peripheral nervous system and musculoskeletal system. While gait changes are common in older people, the presence of gait abnormalities suggests overt or covert pathologies [19]. Although some of these pathologies are easy to identify (e.g., sarcopenia), there are other conditions that represent a diagnostic challenge for the physician. This situation sometimes leads to the question: is this subject ill or just old? [20].

To answer this question, some authors differentiate the normal aging from the non-normal aging using the term "pathological" or "secondary aging." Secondary aging could be defined as an abnormal set of changes afflicting a segment rather than the entirety of the older population [21]. Trying to objectify the non-normal aging process and taking into account that many of these diseases affect the mobility and independence of the subjects, some authors have suggested that secondary aging could be assessed taking in to account the alterations in the gait pattern.

The frequency of gait disorders increase with age; some reports suggest that prevalence rises from 10% between 60 and 69 years to 60% in subjects over 80 years [22]. Some of these pathological motor changes include:

Reductions in gait speed: assessment of gait speed has been described as the sixth vital sign [23]; the preferred walking speed in older adults is a sensitive marker of general health and survival [24]. Although the decrease in speed could be considered normal during aging, some authors suggest that these reductions are associated with an incremented risk for developing mild cognitive impairment [25] and dementia [26–28]; also, gait slowness is related to bradykinesia considered one of the cardinal symptoms of Parkinson's disease (PD).

Reductions in stride length: reductions in stride length have been described in patients with PD [29, 30], subjects with small vessel disease [31], and osteoporotic women with recurrent falls [32].

Increased gait variability: gait variability measures are unaltered in healthy older adults. Studies suggest that an increased gait variability could be associated with an increase of fall risk and could be a marker of pathological conditions such as PD, stroke, Alzheimer, and Huntington disease [33].

Changes in arm swing: PD patients usually exhibit reduced arm swing magnitudes and a higher arm swing asymmetry even in early disease stages [33].

2.1 From muscle to brain: diseases that lead to gait disorders in the elderly

The abnormal conditions leading to pathological aging can be divided depending on the affected system; taking into account that some studies suggest that approximately two-thirds of those who had gait alterations also had neurological disorders, we present a three-level model adapted from the International Parkinson and Movement Disorder Society [19]:

Lower-level disorders: this level includes pathologies that affect muscle, neuromuscular joint, or bones like extreme sarcopenia and osteopenia.

Middle-level disorders: this level includes brain white matter, basal ganglia, and cerebellum disorders. Parkinson's disease, Huntington disease, and cerebrovascular disease are included in this category.

High-level disorders: also called frontal-subcortical gait disorder.

2.2 Lower-level disorders

- Musculoskeletal gait disorders: osteoarthritis (inflammatory process involving bone) and lower limb skeletal deformities are the main non-neurological condition associated with non-normal gait changes in older adults [24]. Since most of these diseases affect articulations and mobility, they are usually assessed by measuring the range of motion (ROM) of the joint and its impact in gait speed. Some of the most common findings are summarized in **Table 1**.

Level	Anatomic localization	Pathology leading to secondary aging	Related motor changes
Lower level	Joints	Foot and ankle inflammatory arthritis	Decrease in walking speed, reduced cadence, increased double limb support, decreased step length, reduced sagittal plane ankle ROM [40]
		Knee osteoarthritis	Decrease in walking speed, larger knee adduction moment, smaller mid-stance knee flexion moment, larger knee flexion angles at heel strike [41]
		Hip osteoarthritis	Step length asymmetry [42, 43], reduced hip ROM
	Peripheral nerve	Diabetic neuropathy	Decrease in walking speed and cadence, shortening of stride length [44]
		Polyneuropathy	Decreased stride time, increased stance time, increased double support time, reduced hip ROM [45]
Middle level	Basal ganglia	Parkinson's disease	Decrease in walking speed, reduced step length, reduced arm swing magnitude, higher arm swing, and step asymmetry [33]
	Basal ganglia	Huntington disease (chorea)	Decrease in walking speed, shortening of step length, shortening of stride length [46], decreased swing time, and increased stance time
	White matter	Cerebrovascular and small vessel disease	Decrease in walking speed, shortening of stride length, decrease in cadence
	Cerebellar	Cerebellar disease	Decrease in walking speed and cadence [39]
High level	Frontal-subcortical gait disorder	Vascular, progressive supranuclear palsy (PSP), late Parkinson's disease, normal pressure hydrocephalus	Gait changes are not specific and are related to the pathology

Table 1.
Gait disorders summary.

- Peripheral nerve gait disorders: peripheral neuropathy is a general term describing disease affecting the peripheral nerves. Prevalence of neuropathic complications of some chronic disease as diabetes increases with aging [34]. Although other neuropathies are rare in elderly [35], some findings are reported in these age groups (see **Table 1**).

- Neuromuscular joint disorders: neuromuscular joint disorders as myasthenia gravis are more frequent in younger women; for that reason they are not discussed here.

2.3 Middle-level disorders

Parkinson's disease: PD is the second most common neurodegenerative disorder; its prevalence is dramatically increasing in older adults [36]. PD is characterized by a depletion of dopamine in the central nervous system leading to cardinal motor symptoms like bradykinesia (slowness of global motor tasks), tremor, postural instability, and rigidity. Objective changes in gait have been reported even in early PD stages and can be used to complement the diagnosis, follow up, and quantify the pharmacological response in these patients [33].

Senile or late adult-onset chorea: chorea refers to a group of movement disorders characterized by the "dancing" appearance of the affected body parts. Although its diagnosis is rare in elderly subjects, there is small a group of patients who debut with symptoms at late ages [37]. To our knowledge, there are no gait analysis studies in patients with late-onset chorea; some of the alterations found in other types of chorea are shown in **Table 1**.

Cerebrovascular disease: stroke is the second leading cause of death and a major cause of disability worldwide. Its incidence is increasing because of the population aging. Gait changes related to stroke depend on the location and extent of cerebral infarction. Given that hemiparesis is one of the most common motor features in the middle cerebral artery occlusion, most studies on gait analysis include hemiparetic patients [38]. See **Table 1**.

Cerebellar disease: cerebellar disease could be related to age-dependent (multiple sclerosis) or aging-dependent (cerebellum atrophy, chronic alcohol consumption, stroke involving cerebellum) pathologies [39]. In our knowledge there is no a single study that evaluates gait changes in cerebellar pathology due to aging. Some of the motor features due to cerebellar disease are summarized in **Table 1**.

2.4 High-level disorders

- Frontal-subcortical gait disorder: this syndrome includes disequilibrium unexplained by sensorimotor deficits, problems initiation or maintaining stepping (freezing of gait), and difficulty with foot placement. Gait changes are not specific.

3. From medical to engineering consultation: importance of the objective gait assessment

The clinical evaluation, within the medical consultation, of patients with movement disorders is usually subjective and has great intra- and inter-observer variability. This variability leads to difficulties in the diagnosis and the follow-up of patients. With the development of new technologies, the objective gait analysis has been more used in the research context. These technological devices allow to detect subtle motor changes even in early stages of the disease, usually when the physician cannot identify them using regular observation (naked eye). In the next sections, we will address the relevance of the objective gait analysis and the importance of precision medicine in the future of the diagnostic, follow-up, and decision-making processes of patients with neurologic and non-neurologic diseases.

4. Ecological assessment

Studies on the human body and phenomena that affect its functioning, such as diseases or aging, have an experimental design in which individuals are subjected to various tests for data collection.

Currently, clinical tests that consist of physical tests such as gait assessment are based on electronic measurement instruments, such as wearables, as seen in the previous section, which seeks to establish objective measures. However, to ensure the quality of the measurements, not only precision is required. Clinical tests may have the Hawthorne effect, which is not desirable.

This effect is that the people under study change their behavior because they are being observed. In the case of gait analysis, this implies that individuals alter their way of walking [47, 48]. In fact, Berthelot et al. [49] affirm that this effect should be taken into account during the clinical tests since they showed different results if they were tested blindly and found advantages in blind conditions for gait speed (GS) and timed up and go (TUG) tests.

The study by Robles-García et al. [50] has explored the impact of the effect on the gait analysis, evaluating 30 people, 15 with Parkinson's disease (PD) and 15 healthy people, 8 of whom were young and 7 elderlies. Gait variables such as cadence and gait speed were measured. The test consisted of walking distance of 17 m with people being aware of being measured and then being told to return to the starting position having to walk the same distance but not being aware that they were also being measured back. They found significant differences in the overt and covert measurement, observing that the gait speed decreases and the cadence increases when they are aware of being measured. They conclude that there is Hawthorne effect in gait evaluation and assert that this is because people seek to perform well when they are evaluated.

In addition, Malchow and Fiedler [51] in another study performed a gait analysis in people with lower limb prostheses, in which the objective was to see if the observer affects the results of the experiments. For this, they used some lies in individuals to measure them without feeling that they were observed and the measurements were compared with a formal evaluation. The results allowed to conclude that the effect of the observation exists in the analysis of prosthetic walking because, in the presence of observers, people under study presented changes of their walking pattern in gait speed, stride length, and stride symmetry.

Therefore, it is sought that the collected data have ecological validity, which means that the environment of the experiment, its methods, and materials should approximate the real world [52, 53]. This implies that by guaranteeing ecological validity, the Hawthorne effect is avoided [54]. Thus, ecological assessments are important in determining measurements that have ecological validity.

Wearables, for example, are an approach to ecological assessment, but it is not the only one. Other studies have proposed the use of a markerless system based on depth cameras and ambience devices defined as the use of multiple installed sensors to collect data related individuals in close proximity to them [55].

For example, the study by Auvinet et al. [56] presents a new way to reconstruct the 3D model of a human body from 3 low-cost depth cameras that can recover a body shape in a 3D space in real time that was more accurate than 20 normal cameras.

In addition, in the study by Muñoz et al. [33] that with a device based on Microsoft Kinect is able to sense the movement of each body part of the individual. The motion information of 25 joints is obtained by skeleton tracking provided by Kinect.

Finally, an example of ambience devices is an intelligent carpet developed by Cantoral-Ceballos et al. [57] using plastic optical fiber (POF) that sense bending, quantified by measuring light transmission. The carpet is able to follow real-time the human footprint which allows calculating spatial-temporal variables of gait.

All previous studies would allow a covert assessment because the systems are portable, mountable in a day-to-day scenario, and no need to use markers or something in particular, but simply by being close to the sensors, which implies that the patients would not require knowing that they are being examined.

Considering that ecological validity allows to obtain reliable results, there are methods that allow maximizing the ecological validity of the clinical tests of gait, which can be improved using a test that implies a double task, in which the person must do a concurrent cognitive task or motor while doing the walk test because the situation resembles real-life actions [52, 58].

An example of this strategy is the study by Wang et al. [59] where it was tried to simulate daily activities to know if the use of a circuit of cameras in the home for the continuous care to the elderly is feasible. The experiment consisted in that patients should move in a scenario that looks like a house, doing daily tasks such as opening the door, sitting on the sofa or stand up, and looking for objects and compare the gait variables extracted from the experiment with clinical assessments. The variables that were measured were gait speed, step length, and step time and were measured during the lapses in which the people are walking in the scenario. The researchers found that there are significant differences in gait parameters between continuous onstage monitoring and clinical trials, which led them to conclude that the clinical trials show Hawthorne effect.

Taking into consideration that ecological validity is important for the evaluation of the gait, in-home survey systems have been developed to monitor and analyze the walking of residents, especially focused on elderly care, sensing people with physiological and pathological aging. The main objective of these survey systems is to prevent and alert falls through algorithms of gait analysis in everyday life, detecting anomalies in the progress of daily activity due to falls; fall-induced injuries are the fifth leading cause of death in older adults [60].

For example, the study by Stone et al. [61] presents a system consisting of a Microsoft Kinect used in depth camera mode, deployed in an assisted living residence for continuous gait analysis. The system allows to measure gait variables continuously to report changes in the resident progress, make fall risk assessments, and detect early anomalies. The system serves to support the tasks of the nurses inside the residence, who can see the reports generated by the system.

5. Future of gait analysis in aging

According to the HealthAge International report, in the year 2015, there were 901 million people aged 60 years or over; by the year 2030, the number will grow to 1.4 billion; and by 2050, reaching nearly 2.1 billion. The "oldest-old" group, people aged 80 years or over, is growing even faster than the number of older persons overall; this represents at least 202 million people in 2030 and approximately 434 million for 2050 [62, 63]. This generates a high interest in researching and developing improvements in current systems that can support and improve the quality of life of the future world population.

As previously mentioned, gait analysis is a process by which a clinical expert performs an objective evaluation of the walk, measuring and generating spatio-temporal variables associated with movements of the lower and upper extremities, posture, and balance. Aging (pathological and physiological) generates changes in the walking pattern, affecting the older population. With the current gait analysis, these conditions can be quantified and obtained, through these variables.

According to the current literature, the main devices to perform this analysis are the gait laboratories (GaitRite or Vicon). Moreover, with the recent technological developments, new devices focused on gait analysis have been developed, such as handles with accelerometers, tracking systems of joints or body segments using cameras, smart templates and force platforms.

In addition to this, with the rise of concepts and technologies such as Internet of things, data science, artificial intelligence, and smart cities and homes, among others, recent developments have focused on contributing to the older population. Such is the case of Roschelle et al. [64], who trained intelligent algorithms through five different sensors (infrared motion, light, humidity, contact, and temperature) and supervision of nurses through telehealth strategies and periodic visits to the smart home for medical assistance (health-assistive smart homes) [64]. This work focuses on assessing the challenges and opportunities generated by information-gathering strategies nurse driven for data analytics. In conclusion, they affirmed that the training of algorithms led by nurses can contribute with tools that allow to monitor and alert about the abnormal state of a group of patients, such as reduction in average activity, slower walk, and increase in the use of bathrooms, without generating daily annoyances or obstructions, since for reasons of privacy, many older adults prefer not to be recorded, with a camera or microphone [64].

Another example is documented by Yacchirema et al., who proposed a system for detection of falls using IoT and machine learning algorithms; this system uses three-axis accelerometers, embedded in a wearable 6LowPan device able to capture in real time the information associated with the movements of the volunteers [65]. However, not only the development of intelligent solutions and low obstruction is enough, it is also necessary to promote the integration of these solutions with the ambient assisted living environment and the work environments of the current aging population [66, 67].

In recent years, the term smart aging was developed, which focuses on promoting care and good aging of the adult population, through ICT technologies, i.e., medical systems and devices, biotechnology, and robotics [62]. This new term will encourage the development of solutions through robotic assistance, such as [68] who proposed a system of rehabilitation of walking supported by a robotic structure (MOPASS), which was tested in patients with 60 or more years, during 5 therapies. The results showed moderate usability and good acceptability. However, a large sample size is necessary to validate and generalize the results obtained [68].

These automated gait analysis systems not only focus on healthy people, many of the systems and current developments contribute to the measurement and diagnosis of patients with different neurodegenerative conditions, such as Parkinson's and Alzheimer's. In the case of Parkinson, Terashima and Saegusa developed a robot-assisted gait training device to support walking rehabilitation for older patients. This device not only focuses on the motor part of the patient, it also contributes to cognitive rehabilitation. The device was evaluated with a Parkinson's patient with episodes of freezing of gait, and the stimuli generated by Lucia, an assistant robot, were effective in breaking freezing. In addition to this, the inclusion of assistant robots allows the clinical expert to focus on the patient's body and gait observation.

Considering the current context of gait analysis, and the recent technological developments focused on wearable and non-obtrusive technologies, the future of gait analysis could focus on the ecological and precise evaluations that allow aging in-place on smart cities or smart homes [69]. This can be obtained through IoT evaluation systems, invisible to the patient, connected with alert and security systems, and that allow diagnosis and decision-making using artificial intelligence algorithms.

6. Conclusions

In this chapter, we have revised not only the normal aging and pathological aging process but also the technical evolution of wearable devices and affordable devices that has been developed for gait analysis, helping physicians and experts in the diagnosis of different conditions which affect gait.

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Conflict of interest

Authors certify that they have NO affiliations with involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements) or nonfinancial interest (such as personal or professional relationships, affiliations, knowledge, or beliefs) in the subject matter discussed in this manuscript.

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Chapter 4

Information and Communication Technology

Delvin Khan

Abstract

Welfare technology is currently in focus in most parts of the world, municipalities, companies, educational institutions, and in central programs and foundations. New products are being developed and tested. The range of products where welfare technology is included is wide. There is a technology built into many aids and there is a new technology with touch screens and video communication for a broad wide of patient groups. It is a broad field that can be included under the designation welfare technology. This chapter explains the trends and scratches the background for the current interest in welfare technology along with science and innovation, which is often presented as a means to solve what is referred to as an aging population with more upcoming chronic diseases, fewer resources and limitations among the healthcare professionals and fewer hands to take care of required needs in healthcare sections.

Keywords: healthcare professional, health and eHealth literacy, technology, patient, healthcare

1. Introduction

An implementation of smart healthcare solutions can improve the quality of patient care to enhanced patient treatments. These kinds of solutions enable healthcare professionals to deliver the needed and adjusted medical treatment in a smarter and faster way [1]. With the increasing world population, the well-known conventional patient-doctor relationship has lost its effectiveness [2]. Hence, smart healthcare becomes very important and can be implemented at all levels in an organization or society starting from tracking vital signs in the elderly to temperature monitoring for babies. In other terms, smart healthcare technologies are not an end in itself [3]. With the implementation of healthcare technologies, organizations can create efficient workflows to ensure a high-quality in-patient treatment. This ambition is only achieved when technologies are put into use and fully utilized. The focus should therefore be in ensuring efficient use of both existing and new technologies [4, 5].

2. Welfare technology

Healthcare technology is an interdisciplinary discipline that links technology and medical/clinical with a focus on developing new diagnostic and treatment methods [6]. Healthcare technology covers a number of technologies, such as medical technology, pharmacology, and biotechnology [7].

The World Health Organization (WHO) has defined and described healthcare technology as the use of medicine, vaccines, procedures and systems—with the associated knowledge and skills—to address a health problem or improve quality of life [8]. Healthcare technology can be defined as technologies used to improve human health [9, 10]. The definition of health technology can be based on the WHO's definition of health: "Health is not just freedom of disease, but maximum physical, mental and social well-being" [11].

At the same time, one can apply a holistic approach to technology that covers technology, organization, knowledge, and product [12]. A user-oriented technology solution helps to maintain or even develop welfare services [13].

3. Smart healthcare in hospital

Smart healthcare feeds friendly hospital that enables patients and preferred partner in using hospital services with the best and newest health technology [14]. This means that hospitals must focus on developing services that motivate the use of healthcare technologies and focus on optimizing the workflows at clinics [15]. A better basis is needed, because without a better basis there cannot be a continuous focus on optimizing the internal processes and the ongoing support and maintenance of health technology and infrastructure [16]. Almost every hospital has the ambition to have effective use of health technology at the highest international level. The ambition to ensure efficient use of healthcare technology is all about how hospitals contribute locally and regionally to increase the quality of patient treatment and realize efficiency enhancements through health technology [17]. Therefore, healthcare technology plays a central role in supporting hospitals. Investing in healthcare technology has huge benefits. Realizing the need gains benefits through increased technology support and utilizing the experience gained at the individual hospitals. This means consistently developing and optimizing the task solution and patient treatment with health technology [18]. Services must be relevant and based on the needs of hospitals. The implementation should be based on deep knowledge, task solving, and priorities [19]. For effective and efficient use of health technology, it requires the greatest possible use of existing technology before developing new technologies with the necessary support for the users' daily lives through qualified and efficient support. The journey toward becoming more efficient and therefore not to forget requires a common center and not a local branch. This means a constant balance for local needs, the overall gains for the region, and the ongoing standardization and follow-up [19].

4. Health technologies and research areas are emerging

Research in new technology is developing rapidly in the health field. Six of the potential technologies to change the way we understand and safeguard human health is listed as follows [20].

4.1 Telemedicine

In term the telemedicine covers a broad concept [21]. This includes treatment and monitoring in patients' own home, for example, through apps, video consultations, and automatic measuring equipment. Most municipalities over the world and regions are investing heavily in these technologies at the moment [22].

Physiotherapists over video can do multi-patient exercises at once, and patients with severe wounds can consult remotely [23]. And people with heart problems can automatically get monitored blood pressure and distance activity. Even though the technology is in use there is still a long way to go [23].

However, telemedicine solutions do not work as intended [24]. In a small case study, a research team has shown a markedly increased mortality among patients treated via telemedicine [25].

4.2 Robotic surgery

Nowadays, robots are used for surgeries when doing operation as gastric bypass, uterus, kidney, bladder, prostate, and colon. The advantage is that the robot surgery can be performed without opening the stomach up and the patient can leave the hospital earlier than with open surgery [26]. At the same time, the robot can see the body in 3-D; it is more flexible and has more precision. The result is less blood loss, fewer infections, less scars, shorter hospitalization, and fewer pains [27].

4.3 Game technology

Among young people, but it also spread quickly in the country's nursing home, where the elderly also had the pleasure and benefit of the machine, because it was both entertaining and good training—a concept called exergaming, exercise and gaming [28, 29].

Since then, gaming technology has really gained momentum in healthcare. Today, games are used, among other things, for rehabilitation after cerebral hemorrhage and for the care of dementia, which through reversal play with old family pictures can get cognitive training and become calmer [30, 31].

4.4 The home under observation

Imagine a home where it is being registered online every time you open the refrigerator door. The floor is pressure sensitive and can follow your walk around the house. In the potted plants, there are small sensors that measure every time you water the plant, and when you turn on the light, it is logged [32].

For some, it sounds like a dystopic surveillance society. But for others, there are great opportunities to prevent hospital admissions among the elderly. The technology has huge potential. For example, pneumonia and urinary tract infections in the elderly can be traced in their everyday rhythms. If one can measure as soon as a breach of the patient ordinary routine occurs, treatment can put in much faster [33].

4.5 Wearables

These days, the body and technology are becoming closer and closer together. The so-called wearables—small pieces of electronics that you carry on the body, for example, in the form of clocks, glasses, or even electronic skin—can become the major revolution in the health world [34].

Today wearables are used to collect all sorts of data about your body: sleep rhythm, pulse, location, and, among other things, how much you exercise [35]. In the future, it will be even more comprehensive: reading insulin levels, anticipating ovulation, or monitoring how much sun you get.

Health technology needs to be adapted to the users. Two basic elements of telescopic health must be present before it works: firstly, the technology must work, and secondly, the technology must be available to the many patient groups that need it. It is not the technology itself that is interesting, but what technology can be used for.

There is one basic element of telecommunications health. The technology must be applicable to all the many patient groups, disease groups, and populations that need it, and where it can contribute valuable to health, safety, cohesion, learning, and quality of life [36].

The patient, or the user, is thus the focal point. There is nothing new in that and it has been a good custom in healthcare and health technology for many years. But the demographic development of the Western world requires even more action than before to put action behind the words. Hence, a lot is needed to achieve a well-functioning telecommunications health when technology is ready.

4.6 Usability in health technology

One of the pieces in this great puzzle is about "usability." It must be easy, safe, useful and motivating for users to use the technology. The technology user interface must be intuitive and tailored to the specific user group, and when needed, the right effort must be organized to equip users to apply the technology properly. Human factors are an important part of health technology [37].

"Human factors" are becoming an increasingly important part as more and more patients with psychiatric disorders are being treated through technology [38]. Three aspects in particular are important in designing telecommunications health solutions, namely:

1. setting precise goals;

2. following and monitoring; and

3. giving feedback and promoting motivation [39].

Algorithms are already being researched, which can detect stress on the basis of voting, and early warning score (EWS) and mobile applications are being tested which, by means of individually adapted questions, can help schizophrenic patients maintain reality and achieve greater security [40].

5. Is technology not interesting?

The technology itself is not interesting? Yes and no. It is only because of the many impressive technological achievements that it is even possible to create new value for patients, citizens, and communities. But the technologies only get value when they are realized for effective and usable health solutions. This includes competent involvement of human factors when developing, designing, and implementing telescopic health solutions [41].

6. Health care technology in practice

Health technology is rapidly evolving and embracing many areas and aspects where both public and private actors are at stake [42]. New terminologies and the development of new technology are constantly demanding health education programs [43, 44]. But there should also be a focus on the meeting between the health professional, the citizen, and the health technology. Furthermore, new technology requires a new set of skills, namely health and eHealth literacy. The concept of eHealth literacy is introduced and defined as the ability to seek, find, understand, and appraise health information from electronic sources and apply the knowledge gained to addressing or solving a health problem [45]. Health literacy refers to accessing, understanding, and using information to make health decisions [10].

In Denmark, telecommunication is a commonly used technology. For example, the purpose of Patient@home is to develop welfare technology for the benefit of patients, the health sector, and society as a whole. Patient@home supports a general development toward more outpatient treatments and expansions to own home followed by home-monitored treatment, care, and/or rehabilitation. The goal of this is fewer and shorter hospital admissions as well as the development of new welfare technology, which in the long term can create jobs, exports, and growth in society. Patient empowerment is a central focus of Patient@home [46]. It is intended that a user-driven development of technologies is in progress so that the patient is supported in taking responsibility for their own health and treatment and at the same time makes it possible to be a patient in their own home [47].

Finland is one of the world's leading countries in terms of health and welfare technology, and it needs to benefit the world [48, 49].

Finland is at the top of the world in terms of IT skills. This is reflected in a well-developed healthcare sector, where virtual reality, cloud-based data platforms, medicine robots, sensor systems, and more, which belongs to everyday life. Today, Finland ranks as the world's third strongest country in health technology, and health technology is the country's largest tech export product [49].

The world faces convincing health challenges in an increased demand and fewer resources. Personal health technology enables a personalized, engaging, preventive, predictive effort in the field of prevention, diagnosis and monitoring, treatment, and assistive technology [50].

Implementation of welfare technology stands high on all municipalities' agenda. Society is challenged by increasing life expectancy, fewer "warm hands," and greater demands for charitable services [51].

When a patient is affected by illness or mister functioning, there is a need for rapid and effective efforts to resume an independent life, and, therefore, welfare technology is an optimal tool that can both contribute to training, support, and compensation and thereby help to promote the rehabilitation process. We already have the technologies.

The challenge is to put them in play in everyday life for the benefit of both patient's and healthcare professionals.

There must not be health technology for the sake of health technology. The technology must be a need to and not nice to have the because it is something that gives value, either for healthcare professionals or patients- and very much for both healthcare professionals and patients. The staff's knowledge and motivation are crucial for a good implementation.

Does the healthcare professional not have the necessary knowledge of how a technology works, loses the face, seems unprofessional, and the technology is not being used? Instead, the staff should be thoroughly dressed so that they can safely operate and, not least, facilitate the citizens to use the technology [52].

Patients can seek their knowledge in the future and have less need to get the healthcare professionals' expert knowledge. What they need is to be facilitated in how they use their knowledge and move on. Health professionals will change from being some who have the expertise to be someone who facilitates patients in using health technology [53].

Healthcare professionals' motivation and engagement are also important to focus on in the implementation phase if they need to be adaptable and open to learning. Learn to take the new technologies, learn how to use them, and learn the new working methods that come with you.

7. Five steps to good implementation

1. Experience of doubtful necessity

Implementation of welfare technology requires change in the organization. One of the most for achieving this change is that healthcare professionals experience the changes as compelling necessary. Does that mean that there must be an order from management that now they will use the technologies? No, the experience must come from the healthcare professionals themselves. Healthcare professionals must be able to see the benefits of using the technologies; for example, they can avoid heavy lifting with lifts and thus prevent many colleagues from being sick due to back problems [54].

If we can go to point out such things in collaboration with the healthcare professionals, so they can see that there is actually a scam here, they get an experience of imperative necessity. At the same time, it is important that we avoid self-satisfaction and "as we always have done." If we fall into it, then there is no change.

2. Compose a working group

Next step is to put together a working group of motivated healthcare professionals who have an experience of imperative necessity and who wants changes. The workgroup should preferably consist of healthcare professionals, but there must also be a management level that can go in and take the organization and allocate the necessary resources, as well as being a technologist, with an overview of what technologies does the organization have and what they can used for. The working group must be present, where things happen.

3. Vision and strategy

The task of the working group is now to set the road. They must formulate the visions and strategies for where they are heading and how they will achieve the goal: to implement welfare technology. A strategy that ensures that staff feel safe using technology and taking it into service must be formulated.

It requires a clear vision and a clear strategy which are to be communicated internally within the working group and which are then communicated easily and clearly to the entire organization. These are not only for the healthcare professionals but also for the patients who come in as they may be able to use it when they get home [55].

4. Short-term goals against the goal

It is important that during the process that the workgroup can set some short-term goals that lead the organization toward the long-term goal: implementing welfare technology. The staff wants to experience and momentum and not get the whole change at once. There may be small instructional videos that present the solutions along the way or walked in living labs where staff can do things, so they are not used to using a new technology for the first time on a citizen, thus appearing insecure and unprofessional in working situation [56].

Give the healthcare professionals some resources and opportunities to practice, for example, in a living lab in a living room, safely and without being hurt because you do not know which button to press.

5. Consolidation via success stories

Finally, the technology must be consolidated by emphasizing all the small success stories that have been underway in the implementation phase. The healthcare professionals and patients must be able and encouraged to share and experience each other's successor so that everyone can see that the technology can be used and that it works [57].

8. Conclusions

Healthcare technology is facing major challenges in relation to both human and financial resources. Therefore, there is a need for innovation. In the area of health and care, it is all about finding solutions where the technology makes us better able to service the patients remotely to free up resources, so that the patients achieve a much greater freedom and independence when the technology allows them to carry out several tasks from home via the technology themselves.

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Chapter 5

Parameterization Methods and Autoregressive Model

Boukari Nassim

Abstract

The first phase for the treatment of random signals is the feature extraction; in this we can find several methods for that. In this chapter, we presented the autoregressive (AR) method, some methods of univariate and multivariate measures, and examples of their applications.

Keywords: feature extraction, autoregressive model, univariate measures, multivariate measures, applications

1. Introduction

In machine learning, pattern recognition and image processing, as well as feature extraction, start from an initial set of measured data and construct derived values (features) to be informative and nonredundant, facilitating subsequent learning and generalization steps. Feature extraction is related to the reduction of dimensionality.

When the input data of an algorithm is too large to process and is suspected to be redundant, it can be transformed into a small set (also called a feature vector).

In the following section, we will review the measures commonly used for the classification of electroencephalogram (EEG) signals, some of which have been used to predict seizures. The majority of these techniques use some type of serial analysis method. In order to detect off-line seizures, time series analysis of an EEG is in one of two groups: univariate or multivariate mathematical measures.

Concerning our work, we will quote methods used for the parameterization of EEG signals as well as for the detection of seizures [1].

2. Multivariate measures and autoregressive model

To parameterize our signals, we use different methods for that; like in our experiments, we have the autoregressive model, with the data of EEG signals founded in Bonn University. The work is realized by the logical of math work laboratory, and in the final, we obtained great results of different orders of autoregressive parameter like an important example in the treatment.

3. Univariate measures

The analysis of univariate time series consists of a single observation of sequential recordings on equal time increments, for example, univariate time series: the price of a company's stock, daily fluctuations, humidity levels, and records of the single-channel EEG. Time is also an implicit variable in the time series. Electroencephalogram analysis using univariate measurements contains a single recording site; univariate linear measurements characterize the EEG time series in terms of amplitude and phase information.

In this section, we describe the univaried linear methods most often used to predict epileptic seizures; common to each method is the requirement of stationarity of the time series, and this implies that the statistical parameters (mean and standard deviation) of the process do not change over time, which is probably not true for seizures.

3.1 Fourier transform in the short term

The short-term Fourier transform (STFT), transforming Fourier (TFCT), or Fourier transform with a sliding window is a transformation used to determine the frequency [2, 3], sinusoidal, and the phase of a local section of a signal. Its square module gives the spectrogram.

We then obtain a family of coefficients or represent the frequency and locate the analysis. As for the Fourier analysis, the knowledge of all the real values will completely and uniquely determine the signal.

The short-term Fourier transform, of a function $x(t) \in (R)$, is defined by means of a window. Thereafter, we drag this window used to locate in time the analysis:

$$W_x(\lambda, b) = \int_{-\infty}^{+\infty} x(t)\overline{\omega}(t-b)e^{-2i\pi\lambda t}dt \tag{1}$$

We then obtain a family of coefficients or represent the frequency and locate the analysis. As for the Fourier analysis, the knowledge for all the real values will completely and uniquely determine the signal. The local discrete Fourier transform is defined by

$$STFT\{x[n]\} = x[m, \omega] = \sum_{-\infty}^{\infty} x[n]\omega[n-m]e^{-j\omega n} \tag{2}$$

where ω is the windowing function.

3.2 Wavelet transforms

3.2.1 Continuous wavelet transforms

In mathematics, a continuous wavelet transform (CWT) is used to divide a continuous function into wavelets [4, 5]. In contrast to the transforming Fourier, the continuous wavelet transform has the possibility of constructing a time-frequency representation of a signal that offers a time and frequency.

The four-time transform in continuous time of the function has the scale of $a > 0$, and the transaction value is expressed by the following integral:

$$X_\omega(a, b) = \frac{1}{|a|^{1/2}} \int_{-\infty}^{\infty} x(t)\overline{\psi}\left(\frac{t-b}{a}\right)dt \tag{3}$$

where $\psi(t)$ is a continuous function in the time domain and the frequency domain called the mother wavelet and the highlight represents the operation of the complex conjugate.

3.2.2 Detective wavelet transforms

A wavelet is a function at the base of wavelet decomposition, which is similar to the short-term Fourier transform used in signal processing [6, 7]. It corresponds to the intuitive idea of a function corresponding to a small oscillation, hence its name.

We can adapt the wavelet transform in the case where we are in a discrete set. This technique is particularly used in digital data compression with or without loss.

We thus define the discrete wavelet transform:

$$g[t] = \sum_{m \in z} \sum_{n \in z} \left(x, \psi_{m,n}\right) . \psi_{m,n}[t] \tag{4}$$

3.3 Nonlinear measurements

For nonlinear measurements, we cite the correlation dimension [8], which makes it possible to distinguish the signals from the deterministic time series; its value decreases before the crisis 9, as well as the dynamic similarity index [9], which follows the spatiotemporal modifications of brain dynamics before the crisis. A crisis.

In addition, there are other methods such as the Lyapunov exponent that is used to identify changes before seizure in the EEG basis for epilepsy surgery [10]. In addition, we must not forget the methods of entropy (SampEn) [11], which characterize by definition the degree of disorganization or unpredictability of the information content of a system, as well as the approximate entropy method (ApEN) [12], a technique used to quantify the amount of regularity and unpredictability of fluctuations over temporal data. ApEN was first developed to analyze medical data, such as heart rate, and then in finance, psychology, etc.

Indeed, to obtain entropy results of good quality, it is necessary to have many data, as well as the reliability of the system and the absence of undesirable phenomena.

4. Bivariate and multivariate measures

Electroencephalogram (EEG) has been used frequently to study synchronization in the brain [13]. EEG is also the technique of choice for various computer interface design applications because of its low cost and easy-to-use architecture.

Electroencephalogram signals can be conceptualized as numerical values (voltages) in time and space (collected electrodes). The techniques available in signal processing and dynamic systems have a long history of applications to the EEG. In this section, we will mention the bivariate and multivariate methods most used in the world of electroencephalography and epilepsy.

4.1 Bivariate measures

For this type of index, the key point is to measure the amount of synchronism between two time series. Here, we review a number of bivariate measures that are often used to compute interdependence between two time series:

a. **Cross-correlation:** Cross-correlation is a simple synchronization measure that is frequently used for linear interdependence capture in the time domain.

The Pearson product moment correlation coefficient between and is calculated by

$$Corr_{y1,y2} = \frac{\sum_{t=1}^{L}\left(Y_1^t - \frac{1}{L}\sum_{t=1}^{L}Y_1^t\right)\left(Y_2^t - \frac{1}{L}\sum_{t=1}^{L}Y_2^t\right)}{\sqrt{\sum_{t=2}^{L}\left(Y_1^t - \frac{1}{L}\sum_{t=1}^{L}Y_1^t\right)^2}\sqrt{\sum_{t=2}^{L}\left(Y_2^t - \frac{1}{L}\sum_{t=1}^{L}Y_2^t\right)^2}} \tag{5}$$

b. **Cross-consistency:** Correlation is a measure in the time domain. In order to obtain the dependency in a certain frequency band, the data must be filtered in this band.

The cross-coherence of two signals and at the frequency f is obtained as

$$Coh_{y1,y2}(f) = \left|P_{y1y2}(f)\right|^2 / \left(\left|P_{y1y1}(f)\right|\left|P_{y2y2}(f)\right|\right) \tag{6}$$

where is the spectral density of cross power at frequency f. Coherence at a certain frequency band can be obtained by averaging above the values in this range.

4.2 Multivariate measures

One approach for calculating synchronization within multivaried time series is to consider all series as components of a single interdependent system and to use multivariate measures; the measures discussed here have been introduced into the literature and successfully applied in the literature. The EEG signal.

4.2.1 Omega complexity

A multivariable time series can be thought of as a representation of. The complexity of omega evaluates the dimensionality of these trajectories in the state space based on analysis of the main components.

Let C = Cij be the matrix covariance, in which the input Cij is the cross-correlation between the time series and calculated from Eq. (2). We calculate the complexity of omega by

$$\Omega = \exp\left(-\sum_{i=1}^{N}\frac{\lambda_i}{N}\log\frac{\lambda_i}{N}\right) \tag{7}$$

The complexity of omega varies between 1 (maximum synchronization) and N (minimum synchronization, i.e., desynchronization). In order to scale the above measurement between a value close to 0 (for minimum synchronism) and 1 (for maximum synchrony), we can calculate omega by

$$Omega = \frac{1}{\Omega} \tag{8}$$

5. Autoregressive method

5.1 Principle

The (parametric) model-based methods are based on the modeling of the data sequence x(n) as an output of a linear system characterized by a rational structure [14]. The AR method is the most frequently used parametric method.

In the AR method, the data can be modeled as the output of a discrete causal filter, all poles, whose input is a white noise. Indeed, the autoregressive (AR) model describes each EEG signal sample as a linear combination of previous samples.

Estimation of the spectral density of a random process is a problem that can be solved by parametric modeling. This modeling makes it possible to represent all the spectral information by a small number of parameters (**Figure 1**).

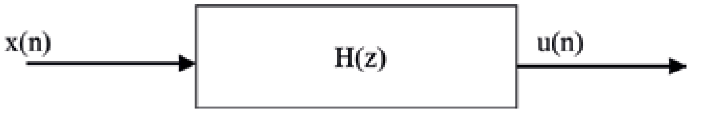

Figure 1.
A parametric model of the autoregressive (AR) type.

where x(n) is the modeled process, H(z) is the all-pole transfer function of the model, and u(n) is a variance white noise. Such a model is governed by the following difference equation:

$$X(n) = -\sum_{i=1}^{p} a_i x(n-i) + u(n) \tag{9}$$

La densité spectrale du processus AR, x(n) s'exprime sous la forme:

$$S_x(Z) = \frac{\varphi^2}{\left|1 + \sum_{i=1}^{p} a_i z^{-i}\right|^2} \tag{10}$$

5.2 Order determination

The best choice of the order of the AR model is often unknown a priori, so it is necessarily practical to postulate several orders and choose the order that seems most appropriate [15]. For this purpose, different criteria based on the prediction error are evaluated to indicate which order of the model to choose.

Two methods have been proposed by AKAIKE, for the choice of the optimal order. The first method, known under the name of FPE criterion (final prediction error or final error prediction), estimates the order of the model which minimizes

$$FPE(k) = \frac{N+K}{N-K} {\varphi^2}_k \tag{11}$$

where ${\varphi^2}_k$ represents the estimated noise variance (or power of the prediction error) and N represents the number of samples of the analyzed signal x(n).

The FPE criterion is an estimator of the power of the prediction error adapted to the estimation of the prediction coefficients directly from the data. The second method, by far the most used, is called AIC or Akaike information criterion. This criterion minimizes.

$$AIC(k) = N \log\left(\varphi^2{}_k\right) + 2k \tag{12}$$

This applies even to the determination of the order of models other than the AR model, for example, MA or ARMA models.

5.3 Coefficient determination

5.3.1 Yule-Walker

The principle consists in determining the link between the unknown AR parameters and the autocorrelation function assumed to be known [16]:

$$C_{xx}(K) = E\{x(n+k)x^*(n)\} \tag{13}$$

Expression of Yule-Walker can be written in the following matrix form:

$$\begin{bmatrix} C_{xx}(0)\ \ C_{xx}(-1)....C_{xx}(-p) \\ C_{xx}(1)\ \ C_{xx}(0)...C_{xx}(-(p-1) \\ .... \\ C_{xx}(p)\ \ C_{xx}(p-1)\ \ C_{xx}(0) \end{bmatrix} \begin{bmatrix} 1 \\ a_1 \\ ... \\ a_p \end{bmatrix} = \begin{bmatrix} \varphi^2 \\ 0 \\ ... \\ 0 \end{bmatrix} \tag{14}$$

5.3.2 Algorithm of Levinson-Durbin

The application of the Levinson-Durbin algorithm to solve the Yule-Walker equation system requires operations only, while the most advanced classical numerical analysis algorithm (e.g., Gauss) requires operations.

The AR parameters are calculated recursively:

$$\left(a_{11}, \varphi_1^2\right), \left(a_{21}, a_{22}, \varphi_2^2\right), \ldots, \left(a_{p1}, a_{p2}, \ldots a_{pp}, \varphi_p^2\right) \tag{15}$$

5.3.3 Algorithm of Burg

The parameters obtained by the Levinson-Durbin algorithm may be greater than unity, resulting in instability of the AR filter.

In order to eliminate this major inconvenience, Burg proposes a computational algorithm based on the minimization of the sum of the progressive mean squared error and the retrograde mean squared error (the taking of the mean is done, under the assumptions stationarity and ergodism, using a simple summation on a set of samples):

$$\xi_p = \sum_{n=p}^{N-1} \left|e_p^p(n)\right|^2 + \sum_{n=p}^{N-1} \left|e_p^\tau(n)\right|^2 \tag{16}$$

5.4 Applications

5.4.1 Transmission of the speech signal

The large flow of information passing through the channels suggests the adoption of coding techniques that reduce the size of the storage memory and the computational volume; in general, it is the delta modulation that is used for this [17].

Another coding technique is to model the speech signal and to represent it by a set of parameters. This type of coding based on linear prediction (AR modeling) makes it possible to carry out a large data compression that can reach a factor of 50 and offers great interest because of its ease of implementation.

This method is based on a very simplified modeling of the mechanism of speech production which consists in applying periodic vibrations or a source of white noise at the input of an AR filter according to whether the sounds to be produced are voiced or unvoiced [18].

5.4.2 Detection of gear defects by vibration analysis

Gear reducers are widely used in mechanics (automotive industry, aeronautics, etc.), highly stressed and complex to dimension, and to achieve.

Some defects appear in these machines, which are due to shocks resulting in local non-stationarity on the vibratory signals.

So, it should be detected early, for which several techniques are in use such as traditional techniques based on Fourier analysis, but the most common techniques use an autoregressive (AR) model.

Indeed, this model gives a good approximation of the estimated spectrum with a relatively small number of samples.

6. Conclusion

In this chapter, we discussed the parameterization methods and their approach to the art; in fact, we approached the univariate, bivariate, and multivariate measures and the method used in this chapter, the principle, algorithms, applications, etc.

Finally, the method is very efficient and very interesting, so it is valid in several areas such as the EEG signal, so this method of parameterization is part of the subject of our work.

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Chapter 6

Connected Insurance Reshaping the Health Insurance Industry

Andrea Silvello and Alessandro Procaccini

Abstract

The role of today's insurer is changing toward a more preventive and digital or connected approach. In this context, connected health insurance has the potential to contribute toward the health and the general well-being of the population. New technologies like e-health and wearables employed by the insurance industry might even help deal with major issues related to the rising number of people, of chronic disease patients, and of elders while keeping them healthier and at the same time protected by insurance. The aim of this chapter is to briefly illustrate the concept of "connected insurance" with specific focus on "connected health" and "wearables" and to present two case studies: Discovery's Vitality program which aims to create healthier lifestyles for its customers through the use of wearables and rewards and ICS Maugeri's MOSAIC project based on AI and predictive models aimed at helping with the management of treatment and quality of life in type 2 diabetes patients.

Keywords: e-health, health, connected insurance, wearables, IoT, diabetes

1. Introduction

The current role of the insurer is extremely different according to country-specific health and welfare policies. Nevertheless, health insurance could contribute to improve current conditions or even solve dilemmas such as how to cope with a rising number of people while keeping them in a good health state and at the same time protected.

The World Health Organization's new 5-year strategic plan addresses what they have identified as the major ten threats to global health in 2019—including noncommunicable diseases, such as diabetes, cancer, and heart disease which are collectively responsible for over 70% of all deaths worldwide [1]. The plan aims to ensure that 1 billion more people benefit from access to universal health coverage, 1 billion more people are protected from health emergencies, and 1 billion more people enjoy better health and well-being. To reach this goal, different types of solutions are required, and all means and mediums available should be employed.

Insurers play an important role in the health-care system and could effectively contribute to such an objective as the one set by WHO toward the benefit of the global health. Though it may seem perhaps altruistic to associate insurers with such a noble scope, the reality is that they, insurers, would also be benefiting from such a scenario. Some forward-looking companies worldwide have understood this opportunity, and so there are examples of insurers that have started to use the "insurer as partner" approach which implies an active role in prevention rather than just being reactive and paying claims when an undesirable event occurs. This new approach has been made, in great part, possible by what we now call “connected insurance” which encompasses Internet of things (IoT), wearables, and other monitoring devices. The reshaping of the insurance industry has already begun, and it will continue based on new technologies at hand. The aim of this chapter is to briefly illustrate the concept of “connected insurance” with specific focus on “connected health” and “wearables” and to present two case studies: (1) Discovery’s Vitality program presented in parallel with Matteo Carbone’s “five value creation levers” insurance model and the company’s aim to create healthier lifestyles for its customers through the use of wearables, gamification, and rewards and (2) Maugeri’s MOSAIC EU-funded project based on AI and predictive models aimed at helping with treatment management, reducing complications, and improving quality of life in type 2 diabetes patients.

2. Connected health insurance and wearables

Connected health insurance presents great potential for both insurer and insured. But let us define the term in a more accurate way. Connected health, as defined in a paper by Deloitte [2], is the convergence of health technology, digital media, and mobile devices and has the aim of helping patients, caregivers, and health-care professionals to access data in a swifter way while improving the outcomes of health and social care. Connected insurance on the other hand refers to an evolution of the insurance business model based on the adoption of IoT technologies which allow the direct connection between all actors of the ecosystem: customers, insurers, and players from other industries [3]. Based on the above, we can say that connected health insurance is a mix of different types of technologies used in health insurance in order to collect data, determine patterns, and create effective incentives and engagement programs aimed at reducing costs related to healthcare and at improving the quality of life of the insureds.

The potential of connected health insurance can be harnessed in a profitable way by properly measuring the risks associated to the clients and presenting them with an improved, better-priced value proposition that may also contribute to improve their general health conditions. For this to happen, the insurance company will have to seek partners from both the technological innovation sphere and medical providers, keeping in mind that its role in the health system is changing from “payer” to “pivot.”

If creating partnerships in order to get more specialized is something that many insurers do nowadays, matters are completely different when it comes to big data analytics and creating efficient customer experiences. There is so much space for innovation, but legacy systems certainly play their role in making the task of innovating more difficult.

2.1 How do wearables fit in the connected insurance scenario?

The technologies range from consumer-driven devices, such as Apple Watch and Google Glass, to those developed specifically for certain applications, such as wrist-worn sensor for measuring the onset of seizure and so on [4].

The uses of wearables are many, but while some are more immediate and easier to apply, others need more time and research to show how they can influence major health issues worldwide. Wearables can be a noninvasive underwriting evidence source thanks to the capacity to collect data and assess risk based on this data in a shorter period compared to a full medical exam. They can also help people improve their lifestyles and habits and at the same time provide added customer value beyond insurance protection. On a more serious note, wearables can reduce the incidence of early deaths from chronic conditions such as diabetes and heart disease, but it can also empower people to manage chronic disease better and even act as early identification system for diabetes and heart disease.

The impact of wearable devices is closely related to statistics and life habits: "the only way to move from a palliative health approach to a preventive model is by increasing the volume of data generated and feeding it with algorithms capable of interpreting them" [5].

The big tech players have also been deeply involved in creating innovative connected health solutions and ecosystems.

Google, for example, aims to build headphones that can track one's health. The company was granted a patent in July 2018 titled "in-ear health monitoring," which combines auditory experiences with health tracking. The aim is to use in-ear devices to collect data on users' health as they listen to their favorite music via their smartphones, tablets, or smart watches. While playing the content, the device would also capture users' body temperatures, effectively creating a database of temperature norms. Over time, the device would be able to compare a person's daily reading against his or her baseline and recognize unhealthy variations in temperature. In the patent description, Google claims that such a feature could lead to "early detection of a contagious disease or other malady" with global health implications, even keeping under control disease outbreaks such as Ebola and swine flu [6]. Nest, who merged with Google, has recently carried out acquisitions such as Senosis, a spinoff from the University of Washington working on health monitoring systems using a smartphone.

Apple recently unveiled an API for application developers to use data stored in its health application so that with the appropriate level of supervision, people can share data with doctors, hospitals, etc. and receive reminders to follow treatment and other administrative tasks [5].

Virtual assistants are an evolved form of e-health, and it's estimated that this type of service could save the health-care industry $20 billion annually. Since virtual nurses are available 24/7, they can answer questions, monitor patients, and provide quick answers. Most applications of virtual nursing assistants today allow for more regular communication between patients and care providers between office visits to prevent hospital readmission or unnecessary hospital visits [7]. If virtual assistants may ease the workload of doctors, another major part of the connected health trend are virtual medical visits performed by real doctors. According to a survey by Mercer, a typical charge for a telemedicine visit is $40, compared to $125 for an office visit, in the USA [8]. When presented with the opportunity, health-care consumers would use virtual care for a variety of activities—from e-visits to diagnosis to group therapy. According to a survey by Accenture, nearly three-quarters of health-care consumers (73%) would use virtual care for an after-hours appointment, and about two-thirds (65%) would use it for a follow-up appointment after seeing a doctor or other health-care professional in person [9].

Amazon is also a heavy investor in healthcare. In 2017, it invested into genomics cancer detection company GRAIL. In addition, Amazon's recent partnership with JP Morgan and Berkshire Hathaway to provide employees with better health insurance signals broader ambitions to upend traditional healthcare [8].

The question remains, how can connected health insurance transform the insurance company from a simple payer of premiums to a proactive player in the customer health journey? Insurers need to stay profitable, and that is perfectly achievable with such a model (insurer that takes "care" of the customer and not just help with the "cure" after a person is ill). There are five main value creation levers to take into consideration according to the theory proposed by Carbone and explained in the book *All the insurance players will be Insurtech* [10, 11].

2.2 Risk selection

Enhancing the underwriting phase with a temporary monitoring based on dedicated devices. As far as the risk selection layer is concerned, connected devices can be indirectly or directly used to select risks at an underwriting stage resulting in low-risk customer acquisition and connected reduction in fraudulent intents.

2.3 Loyalty and behavior modification programs

Loyalty and behavior modification programs lead the client toward risk-free behavior. Behavioral programs are basically approaches that exploit information gathered on behavior to direct clients toward less risky solutions. To this scope a reward system that stimulates safer client behaviors is a key element in this evolved insurance landscape, and programs based on innovative gamification approaches are a must in order to keep clients engaged.

2.4 Value-added services

In other words, developing client-tailored ancillary services allows the insurer to play as an omnichannel medical concierge.

Value-added services consist in the proposition to clients of policy-related services that have a double aim: on the one hand to guide clients toward desired behavior and, on the other hand, to offer perceived value through services to clients. Some ancillary services are proposed to the insured clients in order to exploit relevant data detected; these services could be directly supplied by the insurance company or by means of specialized partners.

2.5 Loss control

Connected insurance allows to use registered data in order to limit the portfolio loss ratio, and it enables the development of claims management processes that permits the insurance company to act more proactively and make the whole process faster and more efficient.

2.6 Risk-based pricing

Risk-based pricing consists in developing insurance policies with pricing linked to client behaviors. Monitoring the "quantity" and "level" of risk exposure during coverage period has become possible. In this sense, the risk can be calculated based on gathered information monitoring with a direct impact on pricing applied to the single customer.

Insurers are beginning to use wearable technology and health apps to reduce risk and improve technical results. Some are educating customers on looking after their own health resulting also in higher customer engagement. Big data gathering and analysis sit at the base of an improved design and product pricing which in turn can encourage clients to adopt a healthier lifestyle. Finally, the very effectiveness of medical treatments can be improved through technology.

Insurance companies have begun to have a more proactive approach by staying in contact with their customers even when they are in completely good health and not only when they seek help themselves. This can be done using innovative systems like wearables and reward schemes. Thanks to the integration between intelligence, connectivity, and better usability, wearable devices can offer interesting opportunities in health and activity monitoring, tracking, personal notifications, and virtual assistance.

3. Discovery's Vitality use case

In order to better grasp the actual benefits for clients and not just for insurers that adopt such an innovative approach, we should take a closer look at the South African insurance player Discovery that can be considered the benchmark when it comes to engaging members and improving their quality of life. Its Vitality program has managed to create a system that not only raises the loyalty of customers but improves their lifestyle and overall state from a health point of view. They apply the five value creation levers mentioned above in a way that brings concrete results for the company and for the insured.

3.1 Loyalty and behavior modification

In the case of Vitality, it is applied as a reward system that stimulates safer client behavior through gamification to keep customers engaged. The gamification strategy used by Vitality is run with the support of an extended network of partners and with the help of wearables and smart objects alongside the well-known smartphone. They create mini challenges related to shopping for food, physical and sporting activities, medical checkups, and so on that if accomplished are rewarded with cash-back, discounts, or other types of incentives. As a consequence, the individuals end up having a more active life (engaged Vitality members exercise 25% more than non-Vitality members), and according to a study released by Discovery [12], they live longer than non-Vitality members: to be more precise, the average life expectance of an insured South African is 67 years, while the average life expectancy of an insured Vitality member is 81 years. Incentivizing behavior change has led to improved health and lower risk—and as a result lower premiums—for members and improved lapse and claim rates for Discovery. Lapse rates for Vitality status are as much as 67% lower than for those policy holders who do not engage with Vitality, while mortality risk is 72% lower for Vitality Gold and Diamond members who are physically active at least twice a week [13].

3.2 Customer loyalty

Customer loyalty is also intertwined, in Vitality, with value-added services. Vitality offers extra services linked to the insurance cover, which have a double aim: on the one hand to guide clients toward desired behavior and, on the other hand, to offer perceived value through services to clients. Very often these services are provided by means of specialized partners. Clients are also rewarded for making healthier choices through PayBack benefit, which has paid out a total of R 2.4 billion to healthier clients since launch.

3.3 Risk selection

Although it is easier to apply this lever to telematics-based auto insurance where monitoring objective data about driving style is relatively easy, the method can also be used when referring to health insurance. The use of connected devices gives the insurer (Discovery) precious data on people's lifestyle and health condition. This helps create a clearer segmentation and thus the ability to select risk in a more effective way. But maybe even more important, the Vitality program attracts younger and healthier people to start with, precisely because this category is proportionately more attracted by the technological, more digital insurance.

3.4 Risk-based pricing

Monitoring the "quantity" and "level" of risk exposure during the coverage period has now become possible. In this sense, the risk can be calculated based on collected information with a direct impact on pricing applied to the single customer. We do not have enough data to confirm that this is being applied through the Vitality program, but it is becoming a standard practice for telematics-based car insurance where the object of the insurance coverage is easier to evaluate than in the case of a living breathing person.

3.5 Loss control

By using connected devices with their customers, Discovery possesses an "early warning" mechanism that can anticipate serious health problems and more expensive claims.

According to Discovery, Vitality Gold status members with heart disease have 41% lower risk claims than members with no Vitality membership. If we are to look at data regarding diabetics, it seems that Vitality Gold members living with this condition have 53% lower risk claims [14].

Another interesting claim coming from a recent presentation by Discovery Vitality at DIA Amsterdam 2018 deserves our attention. According to the results, there is an 18% reduction of hospital and chronic claim costs for the batch of Vitality members that use the Vitality Active Rewards (VAR) alongside the Apple Watch, compared to the group of insured who do not use an Apple Watch. VAR is a smartphone application based on fitness points, which is designed to encourage Vitality members to increase their activity levels by setting weekly personalized physical activity goals and then rewarding users for achieving them. Nevertheless Discovery specifies that the above data are based on a cross-sectional view of the relative claim experience, and it is premature to show the improvement over time given the lower frequency of health claim events. In any case, I show that certain wearables together with the right reward system may have significantly positive results but have yet to be observed over a longer period of time. This is backed up by the data presented by Discovery regarding Apple Watch owners enrolled in the program. It seems that these users are 35% more active than prior to getting the watch. Since the VAR system was launched, there has been a 36% increase in physical activity [14].

The data are very telling, and the implications for ensuring healthy lives and promoting well-being are significant. The Vitality model should be further investigated in order to understand if and how it could work for the general population, not only for specific segments, and to see to what degree innovation driven by insurers and technology companies can be used to benefit citizens in general. The transition to a "prevention-centered" approach is actually a pragmatic decision for insurers because in time, the portfolio tends to change its structure, passing from a majority of so-called "sick" clients to a majority of relatively "in good health" clients [15, 16].

4. ICS Maugeri's MOSAIC case study and its application for the insurance sector

Diabetes is a chronic disease that occurs either when the pancreas does not produce enough insulin or when the body cannot effectively use the insulin it produces. In 2014, 8.5% of adults aged 18 years and older had diabetes. In 2016, diabetes was the direct cause of 1.6 million deaths, and in 2012, high blood glucose was the cause of another 2.2 million deaths [17]. It is estimated that diabetic patients worldwide will be 629 million by 2045 [18].

Diabetic patients have significantly higher risk to develop severe complications generated by the evolution of the pathology compared to nondiabetic patients. Complications arising from the evolution of this disease are peripheral neuropathy, retinopathy, nephropathy, and cardiovascular diseases.

It is well known that insurers either do not cover diabetic patients or, if they do, they require a significantly high premium. This is due to the difficulty to measure the probability of the occurrence of risks associated to these clients.

Therefore, the insurance sector is leaving uncovered a market that is becoming more and more relevant.

ICS Maugeri is a major group of hospitals specialized in rehabilitation medicine offering a multidisciplinary approach in treating diseases and disabilities. ICS Maugeri's research team has developed, in partnership with the University of Pavia, an instrument called MOSAIC aimed at improving the clinical management of patients affected by diabetes mellitus type 2 (T2DM) that can calculate the risk of developing complications related to T2DM in different time scenarios.

MOSAIC uses AI and machine learning which is based on algorithms able to learn patterns and decision rules from data. These machine learning algorithms have been embedded into data mining pipelines, which can combine them with classical statistical strategies, to extract knowledge from data. Within the EU-funded MOSAIC project, a data mining pipeline has been used to derive a set of predictive models of type 2 diabetes mellitus (T2DM) complications based on electronic health record data of nearly 1000 patients.

Based on the results expressed in the research paper, the team has been able "to predict the onset of retinopathy, neuropathy, or nephropathy, at different time scenarios, at 3, 5, and 7 years from the first visit at the Hospital Center for Diabetes (not from the diagnosis). Considered variables are gender, age, time from diagnosis, body mass index (BMI), glycated hemoglobin (HbA1c), hypertension, and smoking habit." The final models are thus able to provide up to 83.8% accuracy in predicting the probability for a diabetic to develop the three main complications and are easy to apply in clinical practice.

It is furthermore demonstrated that intensive multifactorial pharmacological intervention (compared to conventional therapy) leads to significant improvements [19]:

- Additional 7.9 years life span compared to cases where conventional treatment is applied.
- First complication appeared 8.1 years later than in patients with normal treatment.
- General reduction of microvascular complications.

In insurers' terms, this shows that not only risk associated to diabetes can be estimated but also that a proper management of diabetic patients could lead to significant reduction of the risk itself. The question is how can insurers make sure that diabetic patients follow the required therapeutic path?

In fact, diabetic patients are required to follow a rigorous clinical, diagnostic, and therapeutic path in order to manage and control their pathology and try to limit and/or slow down the consequences of this chronic disease. This path involves periodic medical checks, diagnostic tests, as well as continuous and intensive drug therapies, requiring significant effort for patients and their caregivers. Most of the time, the scheduling of such periodic checks must be autonomously managed by the patient, resulting in a progressive reduction of adherence to the required clinical paths. This may lead to severe deterioration of the health state of diabetic patients.

The MOSAIC project has developed algorithms that allow to predict the onset of diabetes-related pathologies, and furthermore, it has developed a platform that allows a real-time monitoring of main risk factors (e.g., hypoglycemia). As part of the program, a face-to-face general examination with a medical doctor is carried out at least yearly, to estimate main risk factors and to identify a personalized clinical, diagnostic, and therapeutic program. The patient follows the prescribed program and is monitored through wearables and telemedicine; this allows to (i) personalize, update, and modify pharmacological treatments, (ii) identify and update the diagnostic path to be performed in order to monitor and reduce the risk of complications, and (iii) identify on-time criticalities that may require timely investigations.

The patient follows the indicated diagnostic-therapeutic program and is also monitored through wearables and telemedicine. As a consequence, this approach allows a significant risk control and, potentially, reduction, allowing the insurance to update the premium yearly.

5. Conclusion

We are all witnesses to a major shift in the way that medical services are delivered. The insurance industry is slowly passing from a one-size-fits-all approach to a personalized approach that looks at individuals and their habits, needs, and their environment. As the World Health Organization predicts a 13 million doctors' deficit at worldwide level by 2035 [20], it's essential for connected health and connected health insurance to evolve in such a way that will allow primary healthcare providers to be much more versatile and flexible in reaching their patients. Clearly, the new paradigm in connected insurance will face several challenges posed by rate of adoption, cost barriers, resistance to change, and privacy aspects, but nevertheless the potential benefits could be significant based on Discovery Vitality case study, for both insurance companies and customers alike. On the one hand, insurance carriers could be able to reduce their costs and at the same time positively influence the health state of their customers. On the other hand, citizens will have improved access to better medical care and health advices at a convenient cost. Further research needs to be done: (1) of Discovery Vitality programs worldwide in order to understand how results vary over time and from country to country and (2) of similar connected insurance programs promoted by other insurance companies with the objective of understanding how changes in the rewards/engagement system reflect on the results.

According to the World Health Organization, just four decisions, physical inactivity, poor nutrition, smoking, and alcohol use, lead to four illnesses—cancer, heart and artery diseases, lung disease, and diabetes—that cause around 60% of global deaths [21]. Based on this information, one can argue that Discovery's model combined with a predictive system such as MOSAIC's could have an even greater impact on avoiding unhealthy behavior and more specifically keeping under control diabetes type 2 cases worldwide by ensuring that patients are correctly managing their condition. The insurer would be increasing its insureds base while helping diabetic patients take control of their chronic disease while also keeping costs in check.

The concept of loyalty and behavior modification programs utilized by Carbone and discussed above could be an evolution or add-on to MOSAIC's approach when applied by an insurer like Discovery. A reward-based system could work as an additional incentive toward keeping diabetics effectively engaged. Taking for granted that diabetics will follow a program step by step and change their behavior toward a desired goal is not something an insurer should do. Here comes the reward as an element that can help in reaching that goal and at the same time give the insureds something to look forward. Even if the real stake for diabetics in such cases is their own life expectancy—which should be motivation enough—the reward element could be a good and fun extra incentive for reaching health goals.

As estimated costs with lifestyle-related conditions (including diabetes) will be 47 trillion by 2030 [22], insurers, the health-care systems, clinical providers, and patients could all benefit in some way from such a program. It would be interesting to look at how this approach could be extended to other chronic diseases and what the state of research is in these other fields.

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