Essays on Digital Health Interventions

The Digitalization of the Catalan Public Healthcare System: an Opportunity for Economic Appraisal

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Res és suficient per a qui el suficient és poc.

Epicur

Nothing is enough for the man to whom enough is too little.

Epicurus

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Abstract

In the Catalan public health system, the provision of services through the use of digital health tools has gone hand in hand with the increasing digitalization of society as a whole. Since these services are often implemented on an experimental basis in a search for innovation, and in the absence of a rule governing the adoption of public policies, they may be exempt from a comprehensive analysis of their pros and cons (an economic evaluation). However, digitalization involves the generation of objective evidence: information stored in databases which can be analysed. There has never been so much information of such good quality. As a result, this dissertation aims to evaluate digital health interventions undertaken by the public health system of Catalonia to analyse evidence regarding its efficiency. The compendium of articles, the main part of this document, consists of the evaluation of three interventions (interconsultation, teleconsultation and telemonitoring). It is concluded that certain digital health tools appear to be cost-effective, and it is recommended that they be supported and promoted; others require further evaluation before a decision can be taken as to whether they ought to be included in the provision of public services.

Resum

Al sistema públic de salut de Catalunya, la provisió de serveis mitjançant eines de salut digital ha anat en paral·lel a la creixent digitalització de l'àmbit personal dels ciutadans. En la mesura que aquests sovint s'implementen amb una voluntat experimental i des de l'òptica de la innovació, i en absència d'una regla d'adopció de polítiques públiques, poden quedar exempts de l'anàlisi integral dels seus pros i contres (l'avaluació econòmica). La digitalització, però, implica la generació d'una evidència objectiva: informació que queda inevitablement emmagatzemada en bases de dades susceptibles de ser analitzades. Mai hi havia hagut tanta i tan bona informació. En aquest context, aquesta tesi té com a objectiu avaluar intervencions de salut digital promogudes pel sistema públic de salut de Catalunya per aportar evidències respecte de la seva eficiència. El compendi d'articles, nucli d'aquest document, es conforma de l'avaluació de tres intervencions (interconsulta, teleconsulta i telemonitorització). Es conclou que algunes eines de salut digital semblen provar ser cost-efectives i es recomana defensar-les i promoure-les; d'altres s'hauran de seguir avaluant per incorporar-les o no en la prestació de serveis públics d'acord amb els seus resultats.

Preamble

While an environmental movement has existed for many years, the recent awareness among the general public regarding the impact of human activity on the environment has called into question the economic model of industrialized societies and has led to some of the first steps which are needed to reduce said impact: people need to consume less packaging and reduce the number of unnecessary journeys by air; while businesses need to rethink the existing model of planned obsolescence and move towards a system of guaranteed sales (a higher price in exchange for a better product) and factor the environmental cost into their profit and loss statements. The common denominator of most approaches being: less and better.

Nevertheless, it must be said that this economic model has also brought society unprecedented levels of material wealth and has led to elevated health indicators (though in both instances, the beneficial effects are not enjoyed equally by the whole population, also in a given economy). When in 1930 John Maynard Keynes wrote “Economic Possibilities for Our Grandchildren” (our generation would be great-grandchildren), he was mistaken: we have not reached a level of welfare saturation which has stopped us from consuming, nor have we reduced the number of working hours since what is deemed a necessity is nowadays not the same as it was a century ago. In recent years, technology (in its broadest sense, in its many different forms) has come to dominate consumption in the private sphere. A member of the public is typically never more than three meters away from their mobile phone, they monitor themselves with portable devices and they can have their entire genome sequenced for a small sum. It is not uncommon for people to replace these devices annually, usually with a view to adding more functionality. Such consumerism feeds the economic model (capitalism) which the citizens exercise and which is largely responsible for the ills which the environmental movement seeks to cure.

The public sector is also participating in the apparent shift in the collective mindset regarding the relationship between people and the environment by implementing policies promoting the generation of renewable energy or by restricting the use of private transport. Its share of these economies ranges from one third to half of the gross domestic product: approximately half of a society’s income passes through administrations. Although a significant proportion of this income ultimately ends up in the hands of the public (e.g. social services or employee remuneration), the public sector has a high level of discretionary expenditure and it ought not to be free from self-criticism regarding its model of consumption. Among its multiple competences, the provision of a health system is one of the main ones in terms of the weight it carries, its impact, and the value it has for the public. Although we know that prevention policies and those related to the social determinants of health are the most cost-effective, society and health professionals often see technology and innovation as some of the most necessary measures, in part due to their susceptibility to the persuasive power of marketing. However, the truth is that evidence regarding their cost-effectiveness in the context of public health systems is scarce. In Catalonia, the economic evaluation of public policies is de facto a rare occurrence. Nonetheless, the technology we need to assess has also changed the possibilities of undertaking an evaluation: the availability of data (largely administrative) and new computer tools (better processors and data analysis programs) have made analyses possible in a way which differs from the costly, approximate and discretionary analyses that were undertaken in the past.

This thesis, which is essentially a collection of studies of digital health experiences in the public health system in Catalonia, is an attempt to make a connection between the ideological motivation of evaluating health technologies and the use of technology to make this assessment. In this binary approach, I have tried to capture the professional experience of two different fields: the economic assessment of public policies and the technologies employed in healthcare. This work aims to convince the reader that thanks to digitalization, the (economic) evaluation of public policies is an opportunity to highlight the value of evidence-based decision-making. And that, in a world full of data, evaluation will inevitably play a leading role.

Barcelona, June 2020

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1. Introduction

1.1. Motivation and objectives

This thesis was essentially motivated by two ideas. Firstly, society has become digitalized: technology has transformed nearly every aspect of life. Government administrations are no exception: both due to their own motivation and the demand from the public, the way of providing the services has changed and continues to change. For example, everything which was previously handwritten is now done at the press of a key; documents which were stored in archives are now stored in cloud-based files which facilitate their analysis; actions which previously went unrecorded are now automatically registered since they involve the use of devices which gather data in one way or another[i]: we are now literally surrounded by them although some are invisible.

Secondly, in the context of public action, the systematic and explicit analysis of alternatives to solve a problem or need, assessed in terms of their pros and cons (the economic evaluation of public policies), has always been seen as crucial to providing the public with the best, most transparent services. This analysis shows the relationship between the resources dedicated to an intervention and the results, nothing more: it does not take for granted that public policies are implemented in the best possible way. It is necessary to take decisions based on empirical facts and, for this reason, it is necessary to have information to help undertake such an analysis.

Evaluation is meant to measure and digitalization measures by its very nature. One is a necessity, the other an inevitable reality. This synergy has a crucial implication: there are fewer reasons not to evaluate, it is easier (in economic terms: the cost has been reduced), assessment makes more sense than ever. One of the areas in the public sector in which digitalization has penetrated more is healthcare. A common factor of all technologies (robotics, artificial intelligence, mobile technologies, telemedicine, virtual, augmented and mixed reality, portable devices, blockchain, 3D bio-printing, etc.) is the widespread use of data: all of these tools generate and use information.

In this context, the general objective of this thesis is to evaluate digital health services within the Catalan public health sector. More specifically, it seeks to answer the following questions: are the digital health interventions implemented by the Catalan public health system cost-effective? And how do they compare with the existing use of resources? I have conducted several studies in order to try to answer these questions. These make up the paper compendium which forms the central element of this work. It is the result of curiosity and the privilege of living at a time in history in which it is easier than ever to ask questions about what can be observed.

The first part of this work examines the current status of digital health and assessment in Catalonia: what is occurring in these two areas which facilitates or hinders the economic assessment of digital health interventions? After the aforementioned compendium (the second part) which includes a representative selection of published articles, the third and final part will give an overview of solutions to the questions above and will discuss the main lessons learned.

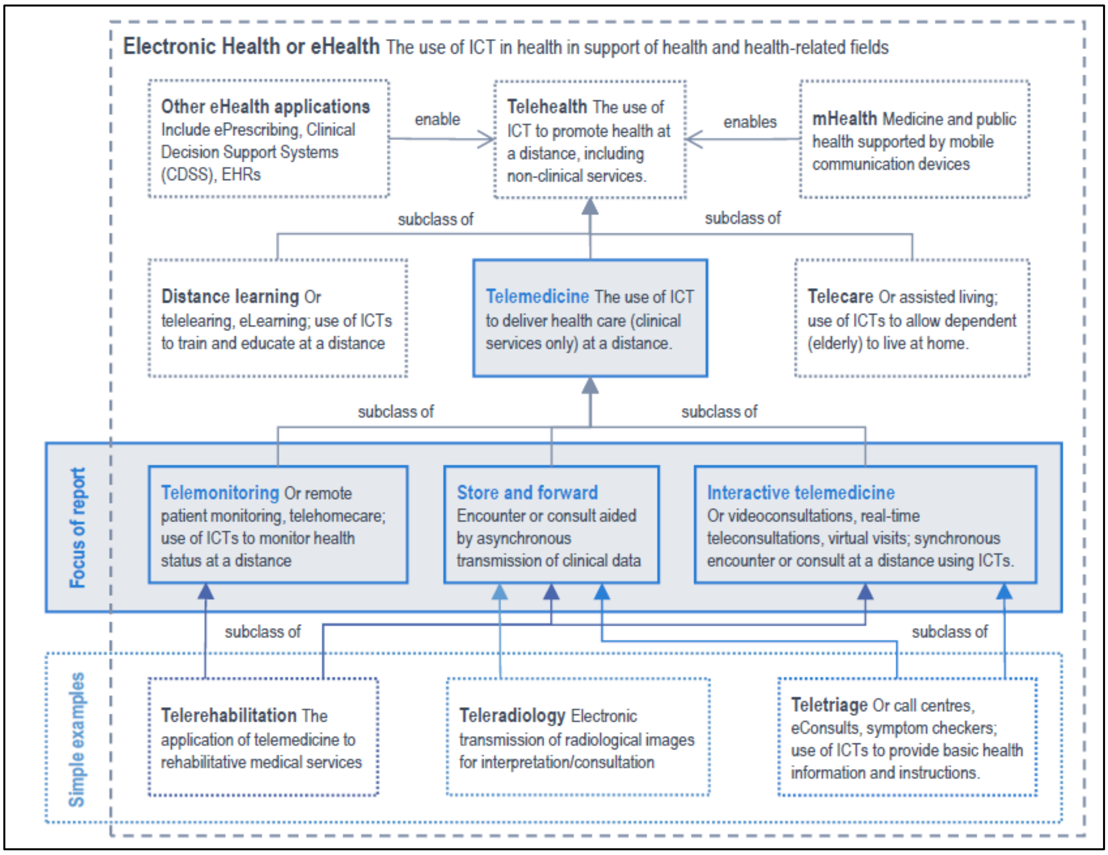
1.2. Digital health

1.2.1. Etymology of digital health

Gunther Eysenbach, editor of the *Journal of Medical Internet Research,* popularised the term eHealth as far back as 2001, defining it as "an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies". In a broader sense, Eysenbach states that eHealth "characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology" (1). More recently and in a more formal way, the World Health Organization defines *cyberhealth* as "the use of information and communication technologies to promote health, whether *in situ* or at a distance" (2).

Since then, several terms (eHealth*,* digital health, telemedicine, telehealth) have been used interchangeably. To date, none has come to predominate and, in practice, they can be used synonymously: whereas it is true that efforts are being made to establish a hierarchy, clarify and specify the meaning of each term (3,4) (Figure 1), up until now, the agents involved have generally adopted one or the other according to their in-house style guide. Robotics, Big Data, artificial intelligence, mobile technologies, telemedicine, augmented, mixed and virtual reality, portable devices, blockchain and 3D bio-printing are some of the technologies which form part of this word family, which have been widely and generically referred to as digital health.

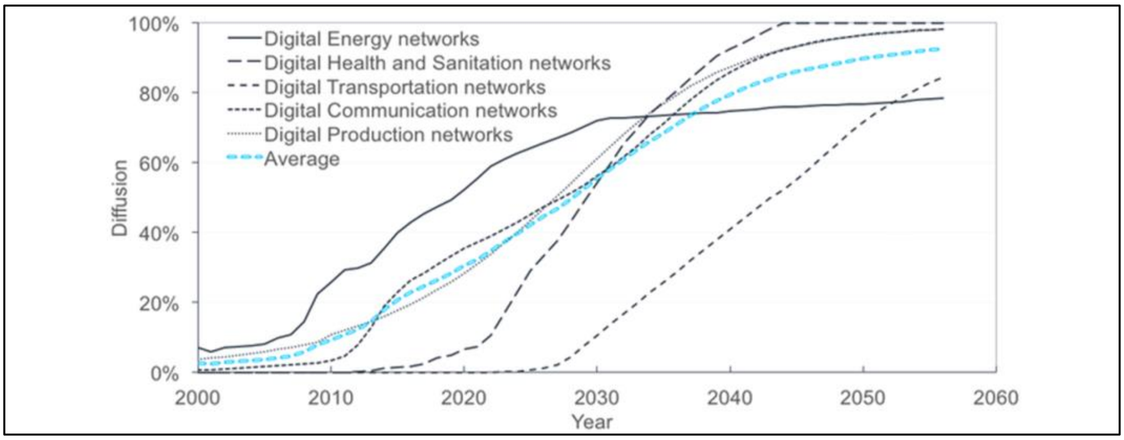
Figure 1. A taxonomy proposal in digital health (OECD 2020)



1.2.2. Technology in health systems

The so-called fourth industrial revolution can be seen not as an extension of the growth of information technology which began in the second half of the twentieth century, but as its expansion due to the speed and extent of its systemic impact (5). According to the World Health Organization, global health expenditure stands at 7.5 trillion dollars and accounts for approximately 10% of GDP (6). Despite its huge volume and the fact that the health sector plays a large part in the development, adoption and use of new technologies, its position in terms of the degree of digitalization of the other economic sectors is still secondary (7). Nevertheless, projections for the next 20 years see health as being the first economic sector to achieve full digitalization, before other pioneering sectors such as energy, telecommunications and industry (Figure 2). The digital transformation of the health sector will involve connecting the numerous health systems and will mean that diagnostics and treatments can be situated in the optimal location by altering the current configuration of healthcare devices currently employed in healthcare provision, which were conceived in the pre-digital era.

Figure 2. Projected diffusion of key technological infrastructures by economic sector (Saniee et al. 2017)



From the perspective of health systems, the process towards digital health is multidimensional and consists of successive waves which health systems experience and implement and which overlap over time in the fields of the digitalization of IT systems, the adoption and use of electronic health records, digital health services, users and patients' access to their personal health folder and the systems' ability to take decisions based on advanced data analytics (8) (Table 1). Meanwhile, economies, governments and societies are digitalizing. Citizens are increasingly using digital technologies in their daily lives and expect the same level of response and ease of use from their health systems. Providers and administrations are exploring new healthcare models by means of digital technologies in the hope that these will help them offer quality care at a sustainable cost (Table 2). Although most of these countries use some form of digital health tools in their health systems, policies vary depending on the type, financing, need, eligibility of the citizens and integration with the face-to-face model: in general, digital health can be found in a wide range of specialties (e.g. dermatology, image diagnosis, neurology, psychiatry), for a number of pathologies (e.g. stroke, COPD) and through various means (remote monitoring, store and forward, real-time video consultations). In spite of interest in them and their growing use, their usage continues to be minor in relation to healthcare activity as a whole (4).

Table 1. Roadmap for the gradual implementation of eHealth (Jakab et al. 2018)

	First wave	Second wave	Third wave	Fourth wave
Infrastructure	Technological and basic network infrastructure	Improved capacity for an advanced and safe infrastructure	Interoperability platform for the exchange of health information	Development of interoperability services between providers (derivations and programming)
Electronic Health Record (EHR)	Digitalization of clinical history	Interconnection of EHR with shared clinical history	Expansion of the interconnection to all health care providers	Integrate support systems to the decision in the assistance routes
eHealth and digital services	First services: prescription and electronic appointment	Expansion of the referral and telehealth service	Territorial expansion of telehealth and telemonitoring	Enable interoperability of third-party telehealth applications
Personal health data	Health portals with health information	Creation and access to personal health history	Improve the personal health history with information and services	Allow connection to third-party mobile applications
Data analysis	Command Centres	Stratification of population risks for proactive care	Improve stratification with mental and social health data	Uses of Big Data and advanced health analysis connected to other sectors

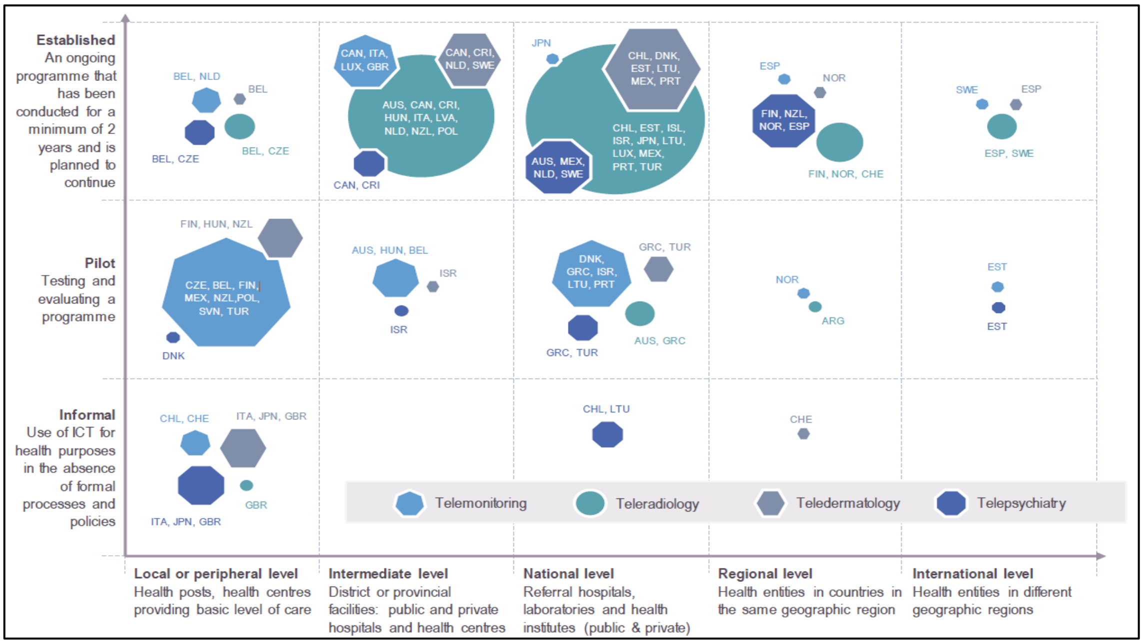
Table 2. Expected benefits from digital health tools

Patients	Professionals	Healthcare providers	Healthcare system
• Reduction of inequalities in access to healthcare • Faster access to different diagnoses and treatments • Reduction of waiting lists with specialists • Continuum healthcare • Avoids travel and waiting times • Higher participation in the care process	• Brings care closer to geographically distant environments • Increases evidence for decision making (interconsultation) • Increased access of general practitioners to other specialists • Avoids travel by professionals • Greater user satisfaction, quality perception and innovative services • Easier, faster, cheaper and more up-to-date access to information through new technologies • New job opportunities for professionals who have availability (e.g. retirees)	• Faster and more timely diagnosis and treatment • Prevents the duplication of services • Increases the productivity of professionals • Mitigates limitations of physical and human resources • Optimizes the use of available resources • Resolves the high demand for services from the public	• Reduction of costs: savings in time and costs of displacement • Improved quality of service • Reduction in waiting lists • Best use and maximising profit from available resources • Dealing with the public's enquiries • Possibility of joining supply and demand, without geographical limitations

At the international level, the most recent studies show that digital health is a varied field in relation to the level of supply and the sophistication of the services on offer (Figure 3). Of the four types of digital health environments analysed, teleradiology exists in most industrialized countries. However, with this exception, most digital health programs (teledermatology, telepsychiatry, telemonitoring) are small-scale pilot projects, focused on a specialty, a health problem and a specific group of patients.

In recent decades, Western health systems have experienced a marked increase in spending, while seeing the introduction of new technologies (9). In 1992, Newhouse's Norms Hypothesis suggested a positive, strong relationship between healthcare expenditure and advances in healthcare technologies (10). Various studies have sought to investigate the mechanisms which underly this relationship (11,12): initially, this increase in expenditure is counter-intuitive if one assumes that technology is more efficient and replaces the traditional methods, thus reducing the unit costs; nevertheless, this “substitution effect” may be accompanied by the expansion of existing treatments or a rise in the quality which increase spending levels, more than making up for any savings. This is in keeping with the Weisbrod Quadrilemma (12), which examines the role of technological change, the level of insurance, the quality of care and cost containment. The expansion of public and private insurance schemes in industrialised countries can also explain increases in resources available to finance innovation. The usage of new technologies may increase spending without actually being accompanied by corresponding improvements in health indicators (13). As a result technology represents one of the most complex to model determinants of health expenditure (14): according to a 2009 study, it might be responsible for between 27% and 48% of the growth in healthcare expenditure since 1960 (15).

Figure 3. Countries reporting use of telehealth, by level of health system and type of program (OECD 2020)



1.3. The digitalization of the public health system in Catalonia

1.3.1. The public health system in Catalonia

Catalonia’s public healthcare system offers universal coverage, free at the point of access, thus guaranteeing the fundamental right to health of all of Catalonia’s residents. The 1979 Statute of Autonomy recognised the Generalitat’s powers in the area of basic health care legislation. In mid-1981 the Spanish state transferred its powers to the Catalan government by means of an official decree, leading to the subsequent launch of the Health Map and the creation of the Catalan Institute of Health, the Public Hospital Network and the Primary Care Reform Bill (9). Catalonia currently has a mixed healthcare model financed by taxes and with equity of access to a wide range of services. All healthcare resources are integrated into a single public healthcare network (the Integrated Public Healthcare System of Catalonia, or SISCAT), regardless of whether they are publicly or privately owned. This is based on a tradition of entities (mutual societies, foundations, consortia and so on) historically dedicated to healthcare. Some 28% of the population also has additional private health insurance without losing their right to public assistance (16–18).

This model serves approximately seven million people who have one of the highest life expectancies in the world (80.7 and 86.2 years for men and women, respectively[ii]). At the sociodemographic level, the Catalan population profile is similar to that of most other industrialized countries, having a demographic pyramid with an inverted trend (18% of the population over 65 years old, 4.3% over 80) and with levels of chronic diseases and comorbidities which are typical of an aging population (one hundred and fifty thousand individuals identified as complex chronic patients). Both the increase in multi-morbidity and life expectancy are factors which encourage the introduction of digital healthcare tools, with an eye to future trends.

SISCAT consists of more than 160 providers with 369 primary care centres, 69 acute care hospitals, 96 long-term care centres and 165 mental health centres. On one hand, this diversity has led centres to create their own information systems and, on the other, the creation of a unified central platform which serves as a communication link: Catalonia's shared clinical history. At the technological level, the fragmentation of IT systems has pros and cons with respect to a fully centralised model: it has led to the deployment of services which meet the specific needs of each centre; however, it may have implied a heterogeneous adoption of technologies which affect patients' equity of access to services. The following is a broader vision of digital health in Catalonia.

1.3.2. Digital health in Catalonia

The *Mapa de Tendències* [Trends Map] is a descriptive, prospective study which aims to analyse the developments in the implementation of new technologies in the public health environment (19). It is based on an annual online survey which has been carried out since 2007 in all SISCAT centres. Its early editions had a strictly technological approach, in an attempt to follow up the introduction of new infrastructure, while in the last few years the study has included an analysis of the value of technology in the context of healthcare for the individual from the perspective of the healthcare professional and those responsible for innovation in each of the centres. The study also records the experiences of different healthcare providers. To name a few examples: robotics using the famous "Da Vinci" device (fourteen units in Catalonia as of February 2020, in spite of a lack of evidence justifying their use in Catalonia does not justify it (20)) which conducts ultra- precise surgery; mobile health technologies (325,000 health and wellness applications available on app markets, some developed by the Catalan health system itself, such as XatSalut (21)); telemedicine experiences (the sending of dermatoscopic images between primary care centres and hospitals through the use of mobile devices); virtual reality (for the treatment of phobias or mental health disorders); artificial intelligence (processing of the eye fundus images for the detection of diabetic retinopathy (22)); 3D printing (to improve diagnosis and surgery); and interoperability (the ability of systems to process information from different sources). In general, the study shows the Catalan system to be in excellent health, in relation to comparable European regions, in terms of the level of use of information and communication technologies, taking the functionalities of the information systems and interoperability to be of particular importance.

It is worth stressing that most of the innovation comes from the providers' initiatives which, in certain instances, are subsequently adopted by the rest of the system. A key example of non-centralised innovation is teledermatology (Table 3), one of the most common applications of digital healthcare in Catalonia, as demonstrated by the number of projects identified in various territories (23). Although each may differ depending on their unique circumstances, they generally consist of an exchange of images in an asynchronous manner between primary care professionals and hospital dermatology specialists with the aim of screening cases and providing a solution by avoiding a face-to-face referral (interconsultation between providers). The centres are particularly pleased by improvements in accessibility and the professionals' satisfaction and have begun to have their effectiveness evaluated and published, as in the case of the Central Catalonia Health Region (24). This territorial overview suggests that the introduction of interconsultation tools in the shared information systems would homogenize the current processes, facilitating the analysis of their impact, and would be very useful for providers, especially the smaller ones, who are less able to make investments.

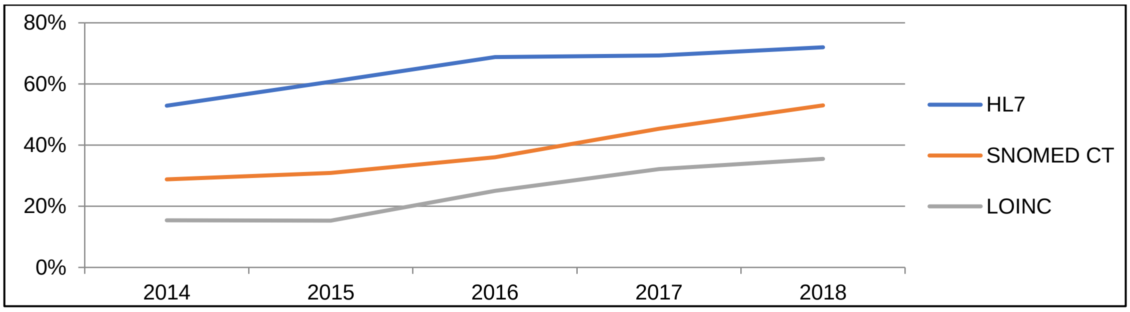
Table 3. Teledermatology projects in Catalonia

Territory	Promoter
Alt Pirineu i Aran - La Seu d'Urgell	La Seu d'Urgell Hospital
Barcelona - City	Hospital Clínic
Barcelona - Alt Penedès	Consorci Sanitari de l'Alt Penedès and Consorci del Garraf
Barcelona - Vallès	Terrassa Hospital
Barcelona - Vallès	Granollers Hospital
Barcelonès - Hospitalet	Consorci Sanitari Integral
Camp de Tarragona - Tarragona	Joan XXIII Hospital
Camp de Tarragona - Valls	Pius Valls Hospital
Central Catalonia - Anoia	Igualada Hospital
Central Catalonia - Bages/Berguedà	Central Catalonia Territorial Management
Girona - Figueres	Figueres Hospital
Girona - Empordà	Baix Empordà Integrated Health Services
Lleida - City	Arnau de Vilanova Hospital
Terres de l'Ebre - Tortosa	Verge de la Cinta Hospital

Note: The list does not include all the entities involved in the healthcare process. For instance, Figueres Hospital conducts its telemedicine program with the Hospital Clínic. In this list, only the former appears.

SISCAT's providers have been adopting electronic clinical history systems for several years. Although it is true that not all the information is shared, the providers are connected to the Shared Electronic Health Record (HC3) and to the IS3 interoperability platform, adopting international standards for the exchange of information (Figure 4). Furthermore, information systems related to medical imaging and electronic prescription exist throughout the country. From the user's perspective, the public have access to their personal health history by means of their personal health folder and can have remote consultation services with primary care services, among others. In addition, a technological platform which will serve to integrate data from the various mHealth elements involved in the care process has begun to be introduced: mobile applications, medical devices and other sensors (25). Together, these innovations and their implementation create a digital health ecosystem which is among the most advanced in Europe and similar to those in leading countries such as Estonia, Denmark and Israel (26).

Figure 4. Evolution of the adoption of interoperability across SISCAT providers



Source: "Mapa de Tendències" 2018. HL7: Health Level 7; SNOMED CT: Systematized Nomenclature of Medicine - Clinical Terms; LOINC: Logical Observation Identifiers Names and Codes. The three are standards of interoperability in the health environment.

At a strategic level, the SISCAT Information Systems Master Plan (*Pla Director de Sistemes d'Informació* SISCAT), drawn up by the General Coordination of ICTs of the Catalan Ministry of Health, serves as a guide for the development of information systems and ICTs. One of the central elements of transformation that the Plan presents is that of health data and its secondary use. The fragmentation of the health information systems means that accessing them for care, management, innovation and research purposes is still fundamental in order to exploit the advantages of a fully digitalized system. In spite of this atomization, the capacity to communicate in a fluid way becomes apparent in projects such as the Data Analysis Program for Research and Innovation in Health (PADRIS, in Catalan)[iii], a service which is available to accredited research centres that provide health data for research. The usefulness of the information available is also reflected in the quality of the research carried out by the Catalan Healthcare Quality and Assessment Agency (AQuAS) with projects such as the "*Central de Resultats*" [Results Centre] (27). The mobilization of professionals in the sector is also robust, as shown by the background of the Catalan Society of Digital Health, part of the Academy of Medical Sciences of Catalonia, which has some one hundred members in the fields of healthcare, management, economics, technology, law and consulting, from different administrations, health institutions, providers and universities. The society has the objective of discussing, providing training and accelerating the implementation of digital solutions in health and social services in Catalonia. Many of its members are also teachers of undergraduate and postgraduate programs dedicated to digital health, information systems and health management in various Catalan universities.

1.3.3. Digital health services promoted by the Catalan public healthcare system

As was mentioned earlier, the legal and organizational nature of the public health system in Catalonia results in the 160 entities which serve SISCAT looking for digital health solutions for their respective contexts. Also, in some cases, the Ministry of Health has promoted at a systemic level some interventions which affect the whole territory. As an example, two are described below.

1.3.3.1. Telestroke, technological support for Code Stroke

Telestroke is a type of telemedicine used for the management of stroke patients. At the international level, it has multiple uses which may include diagnostic support in emergencies, clinical monitoring during the hospitalization phase and support for rehabilitation of the patient with residual disability. With more than 12,000 patients per year in Catalonia, stroke is a time-dependent pathology and requires speedy, high-quality action after its onset, and evidence-based treatment throughout the hospitalization process is essential to prevent death and residual disability, which affects between 35% and 50% of survivors (28). The need to act quickly has led several countries to territorialize care in the form of systems involving community and reference hospitals, their areas of influence and Emergency Medical Services (EMS).

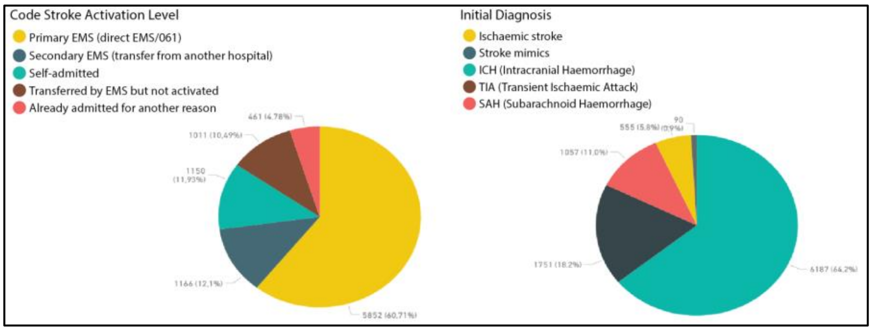
In Catalonia, Telestroke has mainly been applied to expert assessment through the use of telemedicine in patients with acute stroke (Code Stroke patients) who are located in regional hospitals far from large hospital centres and without suitable professional resources. Thus, the Catalan Telestroke can be seen as technological support for Code Stroke: the emergency protocol which leads to the immediate activation of a network of health services aimed at providing urgent, appropriate care to patients suspected of having suffered a stroke with the objective of facilitating access to expert assessment, to avoid unnecessary journeys and to reduce the critical time between the stroke and treatment. The *Pla director de la malaltia vascular cerebral* [Master Plan for Cerebrovascular Disease] was responsible for implementing the Code Stroke system and for regionalising stroke care in early 2006 on the basis of a network of 14 reference hospitals divided into 10 geographical areas which, together with the EMS, guarantee the rapid transfer of patients to these hospitals (29). The network currently includes 28 hospitals with the capacity to assess and treat Code Stroke patients, 14 of which assess patients remotely by a group of vascular neurologists on call through Telestroke. Table 4 specifies the sequence of steps that make up the care process.

Table 4. Code Stroke care process

Step	Description
1	Receipt of patient Code Stroke from EMS/112 or identification of patient who used own means of transport (the local hospital itself activates the protocol).
2,3	Placement of the patient in the stroke box and a quick initial clinical evaluation is conducted. An electrocardiogram is administered and laboratory samples taken.
4	Call placed to 900 100 186 to alert the Telestroke on-call service of the existence of a Code Stroke case at a regional hospital within the network.
5	Videoconference is held. This is always done by the "Telestroke on-call service" at the regional hospital.
6,7,8	Cranial Computed Tomography (CCT), medical image sharing and post-CCT videoconferencing. After this diagnostic test and the assessment of the stroke's severity by videoconference, the expert vascular neurologist will be able to make a medical decision regarding treatment and whether the patient ought to be seen by a referral centre or not. If the decision is made to initiate intravenous thrombolysis treatment (IVT), the on-call vascular neurologist must perform a post-IVT evaluation within approximately 30 minutes of having initiated the treatment. In order to carry out this evaluation, the regional hospital providing Telestroke service must call the reference phone to alert the vascular neurologist of the need to hold a videoconference.

The platform is based on a unique communication system which allows for videoconferencing and the remote control of a camera. This is the part of the Telestroke which allows a vascular neurologist to clinically evaluate the patient. Meanwhile, another platform allows the sharing of cranioencephalic computerized tomography images (which has not yet been integrated into the Digital Medical Image System of Catalonia - SIMDCAT). Communications between hospitals are multidirectional and the platform incorporates a continuous monitoring tool of all the activity and a 24-hour, 365 days-a-year service centre. In accordance with the Catalan Code Stroke Registry (CICat), between 5,500 and 6,500 activations of the Code Stroke protocol are registered annually, a figure which represents some 15 per day. Figure 5 describes code strokes according to the level of activation and initial diagnosis, showing that the majority are cases of ischaemic stroke activated by the EMS. Of these, those which occur in territories far from the reference hospitals are managed via the Telestroke system, approximately one thousand annually (approximately 3 per day).

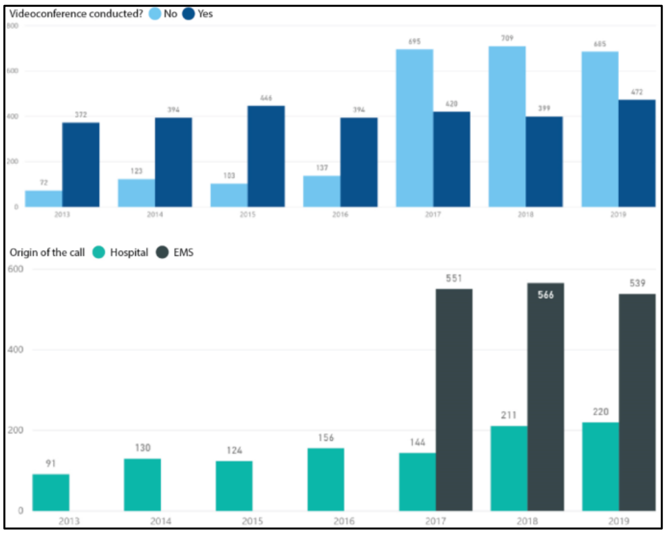
Figure 5. Code Stroke interventions by activation level and initial diagnosis



Source: Catalan Code Stroke Registry (CICat), Catalan Health Service (2018)

The yearly data (Figure 6) shows a notable increase in activations in 2017, when the number of cases is approximately double that of the previous year (from approximately 500 annual cases to over a thousand at present), above all due to the increase in the number of cases handled without videoconferencing from the moment the on-call Telestroke service gives support in pre-hospital triage.

Figure 6. Annual total number of phone calls to Telestroke with and without videoconference, according to origin of the call



Source: Idem

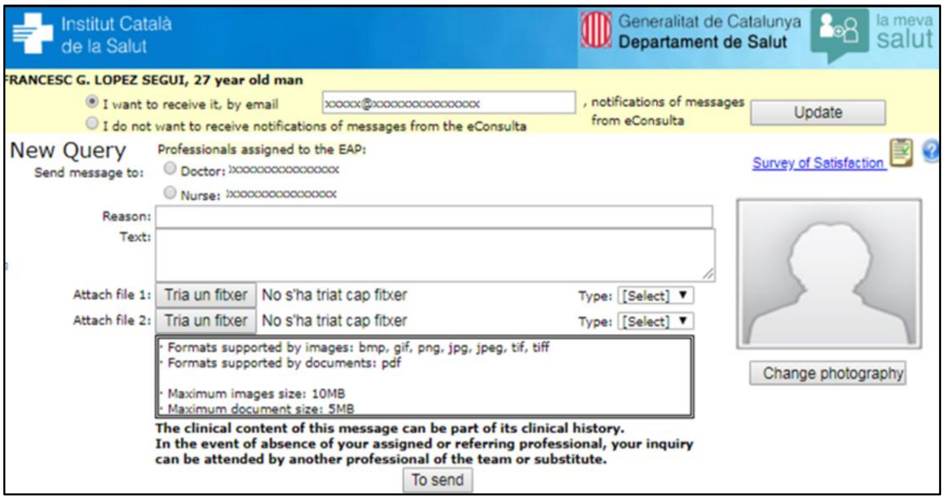
1.3.3.2. Teleconsultation in primary care

eConsulta (eConsultation) is a teleconsultation service which forms part of the primary care information system, complementing the face-to-face service performed by the care teams and linked to the approved services in the patient's personal health folder (*La Meva Salut*). An eConsulation is a means of facilitating communication between the reference medical or nursing professional and the public by means of a safe messaging platform, guaranteeing that the health centre issues replies in a maximum of 48 hours on weekdays. The tool allows files to be attached which can subsequently be added to the patient's clinical history if the health professional sees fit.

It began in 2015, the same year as the personal health folder was begun, with the intention of transferring to a virtual consultation those interactions which do not require a physical examination or which are more logistical or administrative. eConsulta's objectives are to facilitate citizens' access to the health system, to speed up the care process (reducing time and travel) and to encourage the participation and co-responsibility of citizens in the prevention and care of their health (Figure 7). In the healthcare setting, the technology is now available to medical staff (including pediatric care) and some gynaecologists and midwifes, with the hope that social workers and administrative staff will soon also have access to it. eConsulta is seen as a means of mutually agreed communication between the parties. It can be initiated by the patient or the professional, being either completely independent, or as the cause or consequence of a face-to-face visit. At the organizational level, the project is backed by the ICT General Coordination (Information Systems Area of the Catalan Health Service).

A systematic review of the most recent literature on the evidence of the impact of teleconsultation shows that, from the users' point of view, there is a clear consensus regarding their satisfaction, their empowerment and autonomy and their ability to contact health professionals. Acceptability is especially high among chronically ill patients and inhabitants of rural regions. Aspects related to the privacy and security of the data are the main disadvantages mentioned. From the point of view of the professionals, the consensus is that their main concern is being able to manage their time in order to be able to reply to these virtual consultations, although the perception regarding the quality of the assistance offered by the process and its potential to improve health is very positive (30).

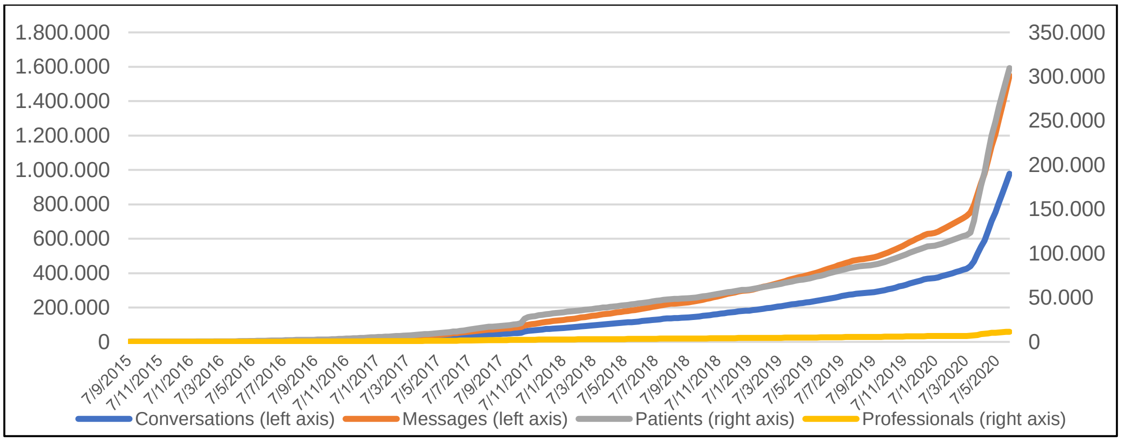
Figure 7. eConsulta's patient interface



As soon as a user sends an eConsultation it generates a visit and each centre can parameterize its duration in the doctor's or the nurse's agenda. In case of absence, the consultation can be referred to another professional as with a face-to-face consultation. When the professional responds, the patient receives an email notification. All consultations made are recorded in the personal health record, which is accessible at all times.

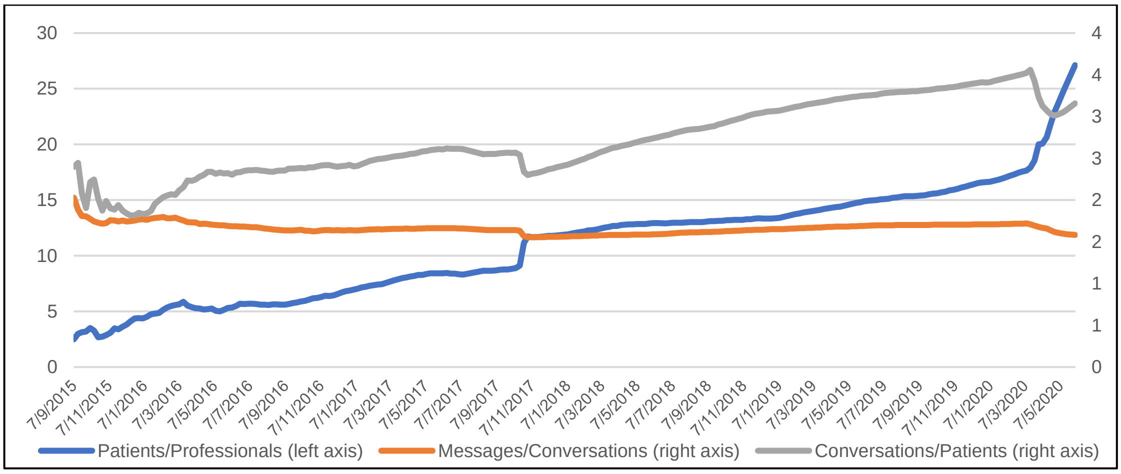
Since its introduction, the service has been extended to all the Primary Care Teams (PCT) in the Catalan public health system. In spite of this expansion, its use in relation to conventional visits is still low (0.9% of total visits). As of 1 June 2020, the tool had recorded 977,801 conversations corresponding to 1,548,902 messages from 309,661 unique users and 11,422 primary care professionals (59% doctors, 41% nurses). Before COVID-19, it was already growing at a rate of 24,000 conversations, 44,000 messages, 5,500 new patient users and 140 new professionals per month, representing a monthly increase of 7%, 6%, 5% and 2%, respectively (Figure 8): during the pandemic, these figures have gone exponential. It is observed that the ratio of messages per conversation is stable at 1.71, suggesting that many conversations contain only one message. Professionals and users have used the tool 17.18 and 3.47 times, respectively, but these figures show an upward trend that indicate that those who use the tool are satisfied with the experience (Figure 9).

Figure 8. eConsultation usage. Number of messages and conversations (left axis) and patients and professionals users (right axis)



Source: eSalut Office (Ministry of Health)

Figure 9. eConsultation usage rates: patients per professional (left axis); messages per conversation and conversations per patient (right axis)



Source: Idem

In terms of the typical eConsultation user profile (Table 5), it is observed that the characteristics of the typical user of the Catalan health system are accentuated: being female(58%), mid-age (49 years old) and with a high degree of comorbidity. This suggests that, in this instance, the generation gap in digital skills is not a particularly limiting factor in the use of the tool.

Table 5. Profile of the person using the eConsultation

	Non-user (n=5,552,889)	User (n=76,657)
Female	2,849,479 (51.3%)	44,581 (58.2%)
Age	48.0 [36.0;63.0]	49.0 [39.0;60.0]
Morbidity-Adjusted Group	3.00 [1.00;8.00]	4.00 [2.00;8.00]
Complex Chronic Disease	114,269 (2.06%)	2,081 (2.71%)
Advanced Chronic Disease	13,470 (0.24%)	214 (0.28%)

From a more qualitative point of view, over the last few years evidence has been gathered in relation to the cases which motivate the use of eConsulta. Two studies, one carried out in the Central Catalonia Health Region in 2018 (31) and the other carried out with a wider sample in Catalonia as a whole in 2020 (32), based on the retrospective and case-by-case notes of professionals who use the tool (reviewing a sample of conversations, one by one), show that the most frequent types of consultation are test management, clinical reasons and medication plan management (Table 6). First of all, and despite the fact that most conversations are for administrative reasons (management of test results, arranging consultations/referrals, sick leave etc.), it is important to note that clinical reasons are among the three most frequent types of consultation, showing that there is a demand for a non-presential care model to solve health problems. Secondly, according to the authors, there is a great similarity between the results of the studies, giving them value and coherence. Thirdly, the reduction of the subset “Other” from the first to the second study may indicate that there is certain preference or specialization in the use of the tool for certain types of consultations.

Table 6. Type of eConsultation, according to two studies

Central Catalonia, n=2,268	%	The whole of Catalonia, n=5,382	%
Management of test results	33.20	Management of test results	26.80
Medical enquiries	17.24	Repeat prescriptions	24.30
Repeat prescriptions	12.18	Medical enquiries	14.20
Management of visits/referrals	7.12	Management of visits/referrals	10.00
Temporary disability management	6.05	Temporary disability management	5.60
Other	24.22	Other	19.10

Table 7. Perceptions by professionals

In favour of its use	Against its use
You can send any enquiry to the health professional, especially to avoid bureaucracy. *Avoid unnecessary travel and waiting time.* *Enhances face-to-face visits.* *Automatically recorded in the patient's clinical history.* *Improved care, quick response commitment.*	*Low confidence in eConsultations being correctly evaluated as part of the usual workload, with the feeling that this could be an extra reason for overloading the agenda.* *Professionals are wary of the possibility of engaging in medical consultations or acts which would have not happened in a face-to-face manner, due to ease of access.*

The freedom of each centre and each professional to use the tool if they so wish, implies a degree of heterogeneity in its uptake. Whilst in some environments there is confidence in its use, there is also reticence in others: Table 7 summarises the professional's perceptions in terms of its use.

With the aim of promoting its use, in 2017 the Barcelona Territorial Management of the Catalan Health Institute decided, in its system of remuneration for Management by Objectives (DPO in Catalan), to use eConsultation indicators as an incentive in the form of variable remuneration (accounting for approximately 11% of the total of the DPO). The scheme was implemented by all PCT operating in Barcelona (both those which had activated the service and those which hadn't) and was nearly fully applied (50/52 of PCT). The high rate of achievement shows that the incentive was useful for the centres having an initial experience with the tool. The following year (2018), with the incentive having been withdrawn, the use of eConsultation doubled.

In short, we can say that eConsultation is a consolidated intervention in primary care and there are plans to introduce it in hospital care soon. The tool has begun to produce some evidence as to its functioning and is accepted by professionals and the public. It is one of the Catalan Ministry of Health's main digital health projects, part of the Health Plan strategy and the services found in the personal health folder and the public information systems.

In conclusion

Catalonia has made significant progress and its level of deployment of digital health tools is a leading example at the European and international level in areas such as the exchange of health information and electronic prescriptions. However, there are many challenges in the present and immediate future due to the acceleration of innovation. The Ministry of Health's Health Information Systems Plan outlines a road map that will require efforts from all agents involved in generating an ecosystem that is permeable to innovation in digital health and its extension to all citizens.

1.4. The economic evaluation of health policies in Catalonia

1.4.1. What is economic evaluation?

Economic Evaluation (EE) is the systematic and explicit analysis of alternatives to solve a problem or need, assessed in terms of social costs and benefits (33). It can take place before an intervention (a plan, program or project) is launched, once it is operational or when it is complete. Its realization is especially relevant before performing it (ex ante) to be able to choose, from the various options that arise, those that are potentially more socially desirable. Once the intervention is completed, the EE (ex post) will be able to evaluate with objective data their real social benefits and costs. The ultimate goal is to have information to help decisionmakers ensure the best possible use of public resources. An EE is therefore not an assessment or analysis of a financial or budgetary nature[iv], but a performance-oriented evaluation of economic and social efficiency. In this context, the adjective "economic" means "complete": it takes into account all the possible (positive and negative) effects. It uses several application techniques, of which the following are briefly highlighted.

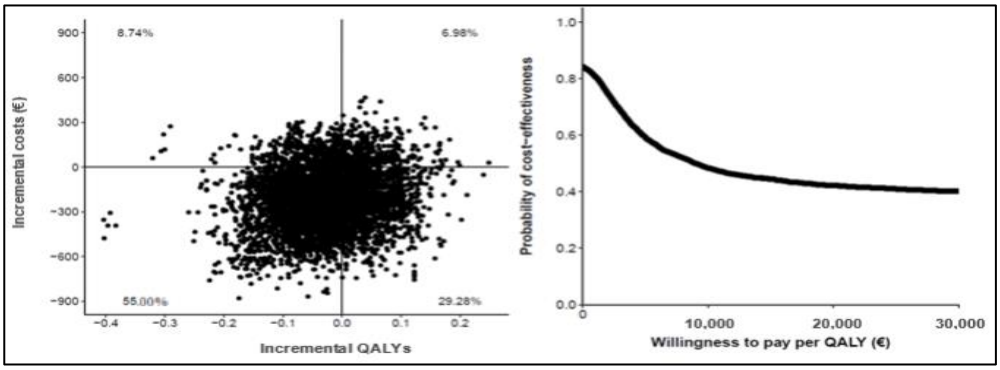
A Cost-Benefit Analysis (CBA) quantifies, in monetary terms, the benefits and costs of a given action for society as a whole (34). This allows the CBA to directly compare results with dedicated resources and determine the net worth of the program. When the benefits outweigh the costs (positive net worth), the adoption of the intervention will be economically justified. Likewise, the CBA allows comparisons to be made between projects which may be similar or different, since it standardizes the unit of measurement of the results in monetary terms. In other words, the determinant of whether a project is more or less socially profitable than another is the difference between its benefits and its costs. A CBA is very clear-cut and it makes it a highly attractive technique. However, its main problem lies in the difficulty of expressing the relevant effects of a policy on a monetary scale, especially in the healthcare sector.

A Cost-Effectiveness Analysis (CEA) is a method for comparing alternative programs and therefore, unlike CBA, it does not aim to determine the net social value of a given action. In this analysis, the costs are measured in monetary units and the results in non-monetary units equivalent to all the alternatives. The ultimate objective is to obtain a cost-effectiveness ratio which expresses the cost per unit of results associated with every program: for example, in healthcare, the cost per year of life adjusted for quality gained. One of its advantages is that it allows different programs to be compared as long as the results are expressed in the same unit[v]. In this sense, the cost-effectiveness plane is a useful graphical representation to help us understand the desirability of one intervention over another. The upper right-hand quadrant represents the space occupied by interventions with a higher cost and worse results, with respect to a base case; in this case, the intervention would be automatically ruled out. The lower right-hand panel represents the space that would be occupied by cheaper and more effective interventions; in this case, they would be preferred over the intervention under consideration. The upper right and lower left quadrants represent cases where costs and results move in opposite directions (lower costs and worse results; higher costs and better results). The main difficulty with a CEA is deciding when it is worth “paying the price” to apply a new program in view of its incremental cost-effectiveness. It is for this reason that decision rules are needed to determine which are the areas of desirability for the adoption of a new intervention. The Cost-Utility Analysis (CUA) is a specific type of CEA in healthcare where the numerator is the variable Quality-Adjusted-Life-Year (QALY).

Finally, Cost-Minimization Analysis (CMA) is another case of ACE in which it is assumed that the results or benefits of the alternatives under consideration are essentially identical, which may be a reasonable assumption in certain cases. In this instance, CMA is the appropriate technique and the only factor to take into account the differential costs of the programs under consideration.

Although all the EE techniques provide interesting information, it is advisable to opt for those which provide a greater degree of comparability of the results and an easier interpretation of the same. Which is why it is advisable to perform a CBA as long as it is possible to evaluate the results of the programme in monetary units or a CEA which measures the results as broadly as possible.

Figure 10. Cost-effectiveness plane (left) and cost-effectiveness acceptability curve (right) comparing the effect on QALYs of Telemonitoring of Crohn's Disease and Ulcerative Colitis versus standard care



Source: del Hoyo (2019) (35)

An important aspect of the evaluation is the timeframe and the perspective that is used (the individual, health centre, health system, society...). While it is desirable that it ought to include as much information as possible (in economic evaluation jargon, the "social perspective", which groups together the preferences of all the agents), the fact that there is no specific standard calls on the authors to transparently contextualize the results according to the methods used.

Cost-benefit, cost-effectiveness, cost-utility and cost-minimization analysis are specific economic evaluation techniques which are best adapted to one or another circumstance, but they are all based on the central idea of analysing the impact of what is measured in terms of the alternatives, in a strict yet holistic manner.

Impact assessment

As described above, an EE analyses both costs and results. It adheres to a series of standards and academic consensus, but this is especially true in the case of results, where a wide range of techniques are used, which can be grouped under the concept of an Impact Assessment (IA). An IA aims to establish whether or not (and to what extent) it is possible to attribute the cause of a change to the intervention being studied (since correlation does not mean causality) (36,37). Doing so in a convincing manner depends on the rigour of the methods, which often are those used in medical sciences (randomized controlled trials, discontinuity in regression analysis, matching, pre-post analysis). An IA is part of any EE and could, by itself, illustrate the effects of an intervention on certain outcomes as well as variables related to the use of resources (for example: the impact of monitoring a clinical parameter on the use of resources by patients with chronic diseases).

In short, EE is a highly informative methodology for decision-making regarding the inclusion or exclusion of an intervention or program in public health coverage.

1.4.2. What does economic evaluation have to contribute to an analysis of digital health interventions?

The purpose of this section is to summarize the evidence on EEs of digital healthcare at the international level. An efficient approach to this matter is a bibliographic search of existing systematic reviews, such as the one carried out by Ekeland et al. (38). In this case, the author indicates that none of them categorically support digital health from the perspective of EE and underlines the need to understand the organizational and social costs from a broader perspective. In order to renew this information, the idea of "revision of revisions" with a publication date equal to or later than 2015 is replicated[vi] (39–46). The following is a short summary of the main conclusions of the eight revisions analysed:

- As commented above (section 1.2.1), the word family used in digital health is not standardized, in some instances they refer to a wide range of concepts while in others they are synonymous with some of their specialities.
- Most studies use cost-minimization analysis techniques.
- The various telemedicine specialities (teleconsultation, interconsultation, telemonitoring, telediagnosis, teleassistance, telesurgery) do not have a specific means of being assessed.
- In general terms, and regardless of the existence of evaluations which show evidence in favour of specific interventions, digital health interventions cannot be defended from an economic point of view.

Similarly, the following is a summary of one of the most well-considered reviews of the literature (47):

Table 8. Conclusions from Kidholm (2012). Adaptation

• Economic evaluations include, for example, the reduction of income or the duration of the stay (Kairy et al. 2009; Clarck et al. 2007). • Deshpande et al. (2008) and Farmer et al. (2005) find that telemedicine studies do not show consistency in their economic assessments. • Kairy et al. (2009) indicate that costs may change over time as technology becomes more democratic or health professionals gain experience. • Rojas and Gagnon (2008) conclude that there is no standard in the set of cost or effectiveness indicators for assessing the cost-effectiveness of home telemedicine. • Seto et al. (2008) note that very few studies consider the indirect costs of heart failure. • Verhoeven et al. (2003) show that it is important to take into account the nature of costs, which can be incremental or decremental for different types of resources.

In short, evidence is scarce and it could be better in terms of its technical quality (very small sample sizes, absence of concrete methods to measure results, etc.). While it is true that specific interventions have demonstrated their positive impacts, the international consensus is that at present the evidence does not support the adoption of technologies in the field of health (48–50). One methodologically sound case serves as an example. The result of an assessment based on a three-arm randomization (conventional care, monitoring with sophisticated digital health equipment and telephone follow-up) found a weak association between quality of life and the two types of intervention and no difference between them. In other words, the increase in quality of life perceived by the user is the same whether the level of digitalization is high (a tablet with various telemonitoring devices connected via Bluetooth) or low (telephone reminders and monitoring), suggesting that technology is not a determining factor in improving the health of the study sample (51).

1.4.3. Does digital health assessment have its own assessment framework?

Although it is true that for many years Health Economics has possessed a theoretical framework for the economic evaluation of interventions (52), until recently (March 2019) there has been no specific proposal for the digital health context (48). Only the most recent assessments have begun to consider the indications included in the economic scope of the MAST model (47), which, in contrast to the new model proposed, do not require specific methods to assess digital health.

As a consequence of this progressive implementation of assessment methods, it is observed that the older the evidence, the more heterogeneous the methods used: the need to start from a single model has been systematically recommended by all authors (53): "*future research efforts should establish common metrics and tools for assessing the effectiveness and cost-effectiveness of digital health interventions".* The application of EE in digital health interventions has a consensus with little support, partly maybe because its experimental and innovative nature always implies "in-itinere" evaluations (while the intervention is being developed) and far from the "laboratory observation" standard contexts, limiting the range of application techniques that can be used in IA. In short, there is unanimity as to the need to strengthen the study of the effectiveness and efficiency of digital health interventions.

Catalonia: is there an economic evaluation of digital health?

In Catalonia, economic evaluation is promoted by different bodies. It is part of the mission of the Catalan Agency for Healthcare Quality and Assessment (AQuAS) belonging to the Ministry of Health, the Public Policies Economic Assessment Area of the General Budget Directorate and the Catalan Institute of Public Policy Assessment (Ivàlua) belonging to the Ministry of Economics. Other entities, with a more academic approach, are more specialized, such as the Centre for Health Economics Research at Pompeu Fabra University, or specialized consulting companies. Healthcare interventions and policies are also evaluated by the providers themselves and their respective reference research centres. They are the ones who ultimately, in accordance with the remuneration model established by the Catalan Health Service, have the incentive to carry out this analysis as the costs and benefits of the interventions have a direct impact on their profit and loss statement.

To which extent are those who carry out the interventions evaluating them? As part of the LATITUD project (23), in mid-2019 the *Fundació TIC Salut Social* (ICT Social Health Foundation) conducted an open survey of every Catalan public health sector provider to analyse the level of deployment of non-face-to-face healthcare in the territory: it collected 157 responses and a series of variables in relation to the assessment in the "Indicators and impact" section. For each of the online interventions, the questions in Table 9 were asked. It is observed that the majority of the experiences have defined evaluation of results indicators (71%) and declare to measure the relationship between the intervention and the use of in-person services (56%) although results show that neither economic or health impacts are registered. While a large number of experiences (45%) are said to have documented, in some way, the impact of the project, none included them despite the poll explicitly asking them to do so.

Table 9. Questions related to the evaluation included in the LATITUD survey (2019)

Question	Type of response
Have success indicators been defined?	Yes, No
If so, which are they and what is their current status?	Open text
Have the costs associated with the intervention been measured? (infrastructure, staff, training, other indirect costs)	Yes, No
Has the relationship between the intervention and the use of in-person services been measured?	Yes, No
Has the economic impact of the intervention been analysed?	Yes, No
Has the impact of the project been documented?	Yes, No

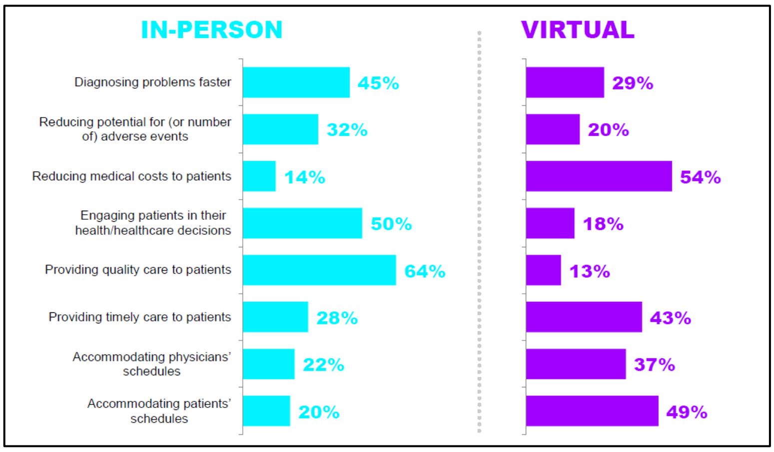
In short, very little evidence is published in Catalonia regarding the economic assessment of digital health: the exceptions suggest, for example, that time and distance of a journey is a determining factor in deciding the goodness of digital health services (54,55).

Why do we see so little economic evaluation in the digital health field? Firstly, it may not be performed because it is perceived as expensive or not very useful. In the absence of an explicit incentive system, self-evaluation may not be in anyone's best interests. It is a type of evaluation which is generally frowned upon (the binomial of "money" and "health") and often the databases that need to be cross referenced for proper analysis are not accessible or digital health technologies are rapidly developing and iterating (48). Secondly, such an evaluation might be carried out but it is not published due the publishing costs, because the results are not good or out of a fear that the financer might take advantage of the potential savings and reduce funding. This possibility is further explored in section 1.4.4.

Social pressure versus evidence-based decision-making in the adoption of technology in public environments

The technological actors present with proposals which accelerate the digitalization of health by the private consumption environment which de facto puts pressure on the public sector: the contractor is pressured to incorporate technologies lacking proven effectiveness and efficiency. A good example would be the idea that digital health reduces costs (56) (Figure 11).

Figure 11. Which are the three main advantages of in-person visits and virtual consultations?



In the digitalization of the private and personal context, the logic of economic evaluation is more decontextualized and consumption more susceptible to media and marketing pressures. The high expectations generated by commercial environments could be pushing public health entities to adopt technologies without clear evidence (57).

1.4.4. Digital health payment models

Healthcare systems have complex purchase and payment models adapted to specific cases. The use of digital health tools implies different economic relationships with providers and patients. Some examples are listed in Table 10, based on a study of the OECD countries (4). Catalonia, like Iceland (and like many other countries not included in the analysis), does not have a specific payment model depending on whether the provision of healthcare was carried with or without digital health tools. However, the absence of a specific economic model may also lead to ideas as to which mechanisms would encourage its use.

The Catalan Health Service, the Catalan service contractor, has the mission of guaranteeing public, comprehensive, quality healthcare to the entire population by adapting its services to their needs. It is in charge of planning, financing, buying and evaluating health services. The portfolio of services consists of those which the public health system of Catalonia has at the disposal of the population with the aim of standardising, ordering and managing the interventions which have added value. It is the contracting body of the providers of the Integrated Healthcare System of Catalonia. In primary care, the payment model between the Catalan Health Service and the primary healthcare providers is capitative (based on the assigned population). In hospital, social and mental health care, the payment is a fixed amount for care given. This remuneration scheme, which the introduction of digital health provides the opportunity to rethink how health services are purchased, has several implications for the adoption of non-presential care models which are described in Table 10.

From the providers' point of view, it is argued that the lack of economic incentives is a barrier to the adoption of digital health services. In part, the fact that they do not form part of the portfolio of services –the set of activities which form part of the contract– does not work against the providers as they each have freedom to operate in one way or another, ensuring the quality of standards are maintained as well as the right of access established by the contractor. This implies that any technology or innovation that can potentially help reduce costs benefits the centre itself: at the same retribution rate, the discount favours the service provider. Therefore, without wishing to assume that digital health services are more cost-effective than the conventional care, which is currently uncertain in the Catalan context, the contractor offers an implicit incentive to providers (which affects the management and care sectors differently) to provide a service in the way each considers appropriate. In the absence of a cost-effectiveness threshold like that found in the British system, which quantitatively defines the limits of the desirability of an intervention for it to be incorporated into the system, these incentives represent a reasonable regulatory framework for the Catalan public context in the short term.

Table 10. Economic payment models of digital health services (OECD 2020)

Country	Model
Argentina	Telemedicine consultations in the Italian Hospital of Buenos Aires are financed "fee-for-service" in haematology, but in a capitative form in cardiology.
Ireland	There are pilot projects with public funds, but most telemedicine services are provided and financed privately.
Czech Republic	The insurance company only reimburses for services provided face-to-face: telemedicine is paid "out of pocket" or by means of specific contributions normally made to small-scale projects.
Poland	The "National Health Fund" finances a limited number of telemedicine services such as cardiac rehabilitation but is planning to expand them to more services.
France	Patients can request the reimbursement of video consultations to their insurers if they have visited the hospital in person during the previous 12 months, except for urgent care or when the patient's usual doctor is not available.
Slovenia	Every year, negotiations are held to determine which services will be covered by the insurance through "fee-for-service" payments. Currently, only the Telestroke is financed.
Norway	The telemonitoring services operate in certain municipalities (e.g. Oslo) without any cost to patients, financed by municipal budgets.
Iceland	There is no difference in the payment and reimbursement of a face-to-face consultation or a teleconsultation.
Portugal	Various payment schemes with specific incentives promote the use of telemedicine services (additional funding for providers).
Australia	Telemedicine is funded by the Medicare benefits system through service fees, from other specific state and national sources. The trend is towards the capitative model to encourage the generalization of innovative practices.

This policy has been combined with the availability by the administration (through its Master Plan for Information Systems) of making large systemic investments with a high fixed cost that providers cannot assume individually. This has been the case, for example, with the implementation of the shared medical record (*Història Clínica Compartida de Catalunya* - HC3), the IS3 Interoperability platform, the personal health folder, electronic receipts and other clinical management systems such as those used by the laboratory and radiology services. The application of single or combined solutions is detrimental to their adaptability in each of the centres while it favours the homogenisation of the quality of service between providers and territorial equity and avoids a discretionary element in the relationship between economic investment and the contracted products' performance in each of the centres.

This balance of centralization and decentralization seems to be appropriate to the Catalan multi-provider system and functions in those instances in which the provider can effectively choose: if the cost of introducing a new technology or innovation is higher than the centre's economic capacity, they are unable to exercise certain investment options. Therefore, there is a subjective threshold for its adoption, which depends on the centre's economic capacity, the inherent rigidity of its legal nature and the political will of the contractor in relation to co-responsibility with the risk. This implies that the Catalan Health Service has to be receptive and proactive in assessing these potential technological changes that can be addressed as systemic.

In addition, it would be advisable to ensure that the remuneration agreed with the contractor does not decline with a hypothetical reduction in costs on behalf of the healthcare provider. If a provider expects that any changes in conditions will imply working with a greater budgetary restriction, they would lose any incentive to operate with more efficient technology. In this context, it should be made clear that the provider will be able to capitalize on the outcome of an innovation over a sufficient time period, starting from the publication of the corresponding cost-effectiveness analysis. In this way, the savings generated by new technology would be shared between the provider, who is the one who has motivated it, and the Catalan public health system, and transparency would be encouraged with respect to the costs and benefits of each of the interventions analysed.

Nevertheless, in pay-per-service cases, where the contracted activity is not exceeded, the remuneration model acts as a perverse form of incentive which can encourage face-to-face care. In this sense, initiatives aimed at reducing face-to-face care (digital health tools in the environment of preventive and proactive medicine or encouraging reductions in travel) represent a conflict of interest for the provider: they are an 'own goal' at the managerial level. In general, it is reasonable to assume that providers will adjust their way of working to their payment model: it is well known that they generate relatively more procedures and diagnostics directly paid by the contract. In this sense, therefore, it is true the providers' complaints that the absence of a specific remuneration model for these types of services does not motivate their use.

However, is it possible to attribute to the payment model a hypothetical insufficient implementation of digital health tools by centres, or does the argument mostly favour calling for better financing? On one hand, based on the available evidence, it could be that providers perceive the use of digital health tools as more efficient and that they believe that it is advisable to introduce them. There are other limits to its adoption, however, such as insufficient economic capacity, risk aversion and organizational barriers to its implementation (a plausible hypothesis since some of them only imply a transformation of processes with existing technology, at no extra cost). Thus, for the government it is necessary to facilitate the adoption of these innovations from the administrative point of view. On the other hand, based on the available evidence, it may also be the case that healthcare providers are not convinced that the implementation of these innovations implies greater efficiency and, therefore, they are not willing to assume the inconveniences derived from their adoption. In both cases, contradictions within the economic model cannot be used as a pretext for limiting the implementation of digital health services.

2. Compendium of articles

2.1. Context

The 18 articles that have been carried out in the framework of this research were all designed to evaluate digital health interventions which exist in the Catalan public health system (appendix 4.1 lists them all)[vii]. This section presents three which have been chosen in order to represent three different technological environments (teleconsultation, telemonitoring and interconsultation) and because they include, more or less explicitly, three uses of new technologies which serve to make assessments (the use of Big Data, artificial intelligence and free access tools).

The first, *The Prescription of Mobile Apps by Primary Care Teams: A Pilot Project in Catalonia*, is the result of a pioneering initiative in public health systems worldwide. The AppSalut project aimed at telemonitoring citizens with chronic illnesses, respiratory illnesses and alcohol addiction by means of mobile apps prescribed by primary care professionals and integrated into public information systems. The integration of primary data (generated by the population) to complement institutional Big Data is the starting point of proactive medicine, which is perceived by the sector as necessary to meet the increase in demand expected over the coming decades. There are experiences that suggest that remote monitoring of citizens is an effective measure to reduce the use of face-to-face resources and avoid clinical complications. The article, which reviews an evaluation of the implementation of the pilot project, summarizes the analysis which was used to rethink the intervention and expand it with the use of portable devices (25).

The second, *A Cost-minimization Analysis of Provider-to-provider Telemedicine Compared to Usual care in Catalonia: More Agile and Efficient, Especially for Users*, is based on a similar previous study which analysed the cost differences of interconsultation between primary care and hospital care compared to conventional care in the initial stages of the intervention (2016). On one hand, the rapid growth in digital health interventions means that analysing them once they are implemented is complementary to pilot projects. In order to update the study, a systematized assessment tool was proposed using a free access tool (the statistical package R combined with Google Maps technology) which could be used, at a very low marginal cost, to scale up the analysis to a larger territory or at a different time in the future. The study is an excellent example of how it is possible to take advantage of "modern" tools (in relation to conventional assessment) to generate systemic and continuous assessment schemes.

The third, *Teleconsultations between Patients and Healthcare Professionals in Primary Care in Catalonia: the Evaluation of Text Classification Algorithms Using Machine Learning*, is a pilot experience in the use of artificial intelligence-based applications for assessment in the context of digital health, in this case to study the impact of teleconsultations on the use of face-to-face resources. Although working with an excessively small sample (in relation to the possibilities of the tool), the experience serves as a precedent for the use of Natural Language Processing techniques for the assessment of digital health interventions.

These articles are presented below. Their references, which introduce the three following sections, are linked to their respective public versions.

2.2. The prescription of mobile applications in the context of primary care

López Seguí, F; Pratdepàdua Bufill, C; Abdón Giménez, N; Martínez Roldán, J; Garcia Cuyàs, F. The Prescription of Mobile Apps by Primary Care Teams: A Pilot Project in Catalonia. JMIR Mhealth Uhealth. 2018

The Prescription of Mobile Apps by Primary Care Teams: A Pilot Project in Catalonia

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Abstract

Background: In Catalonia, the *Fundació TIC Salut Social*'s (ICT Social Health Foundation) mHealth Office created the AppSalut Site to showcase to mobile apps in the field of health and social services. Its primary objective was to encourage the public to look after their health. The catalogue allows primary health care doctors to prescribe certified, connected apps, which guarantees a safe and reliable environment for their use. The generated data can be consulted by health care professionals and included in the patient's clinical history. This document presents the intervention and the major findings following a five-month pilot project conducted in the Barcelona area.

Objective: The objective of the pilot study was to test, in a real, controlled environment, the implementation of AppSalut. Specifically, we tested whether (1) the procedures corresponding to the prescription, transmission, and evaluation of the data functions correctly, (2) users interact successfully and accept the tool, and (3) the data travels through existing pathways in accordance with international standards. The evaluation is not based on clinical criteria, but rather on the usability and technological reliability of the intervention and its implementation in the context of primary care.

Methods: The project was presented to the Primary Care Team (PCT) participants to encourage the involvement of doctors. The study involved at least 5 doctors and 5 patients per professional, chosen at their discretion and in accordance with their own clinical criteria. An initial consultation took place, during which the doctor discussed the pilot project with the patient and recommended the app. The patient was sent a text message (SMS, short message service) containing an access code. When the patient arrived home, they accessed their personal health record (PHR) to view the recommendation, download the app, and enter the access code. The patient was then able to start using the app. The data was collected in a standardized manner and automatically sent to the system. In a second visit, the patient looked at the data with their doctor on their clinical station screen. The latter was able to consult the information generated by the patient and select what to include in their electronic health record. In order to assess the performance of the system, three focus groups were performed and two ad-hoc case-specific questionnaires, one for doctors and one for patients, were sent by email. Response was voluntary.

Results: A total of 32 doctors made 79 recommendations of apps to patients. On average, the patients uploaded data 13 times per prescribed app, accounting for a total of 16 different variables. Results show that data travelled through the established channels in an adequate manner and in accordance with international standards. This includes the prescription of an app by a doctor, the patient accessing the recommendation via the PHR, app download by the patient from the official app stores, linking of the patient to the public platform through the app, the generation and visualization of the data on the primary care workstation, and its subsequent validation by the clinician.

Conclusions: First, the choice of apps to be used is fundamental; the user's perception of the utility of the proposed tool being paramount. Second, thorough face-to-face support is vital for a smooth transition towards a more intense model of telemedicine. Last, a powerful limiting factor is the lack of control over people’s ability to use the apps.

JMIR Mhealth Uhealth 2018;6(6):e10701. doi:10.2196/10701

Keywords: mobile apps; apps; mHealth; primary health care; telemedicine; telemonitoring

Introduction

Background

As part of the Catalan Ministry of Health, the *Fundació TIC Salut Social* (the ICT Social Health Foundation) works to promote the use of information and communication technologies (ICT) in the field of public health and social welfare. Its main tasks include the observation of new trends, monitoring of emerging initiatives and the provision of services to certify products, systems and apps. In this context, the mHealth Office was created in early 2016 with the aim to bring patients closer to health and social mobility services so that they can interact with the health system in a trouble-free, personal way. The Office created a website featuring mobile apps in the field of health and social care for medical professionals and members of the public, a mechanism for accrediting apps, the development of mobility standards and a means to monitor experiences with health-related apps. As part of the framework of services that meet the corresponding interoperability standards, the Digital Health Platform (DHP) acts as a repository for this information. It also facilitates interactions between members of the public (providing the user with the information they have generated through the use of one or more recommended apps) and doctors (providing support in monitoring the patient's status and allowing the treatment to be p-ersonalized and adaptable to their needs).

App Catalogues - The AppSalut Site

Easy to get, easy to use and insanely cheap. The use of mobile apps for health management has been promoted both by independent reviews and public initiatives [1]. In the former, the app stores themselves (Google, Apple, Windows, Amazon, Blackberry) rank the apps in their catalogues according to the opinions of expert or user ratings [2] [3]. Nevertheless, they are unable to avoid significant heterogeneity in their quality [4] and safety standards [5].

Likewise, countless leading websites feature health apps, either exclusively, such as iMedicalApps and Fundación iSYS's iSYScore [6], or only as one of their numerous areas of interest (Android Authority, ForbesTech). As for catalogues aimed at the public sector, we find fewer initiatives: for example, the United Kingdom promotes its "Digital Apps Library," which is still at the design stage; at the regional level, the Andalusian Health Service maintains its "Catalogue of mobile health apps" recipients of its AppSaludable label, its own accreditation process.

In Catalonia, the *Fundació TIC Salut Social*'s mHealth Office created the AppSalut Site as a central, wide-reaching project. It is intended as a showcase of mobile apps in the field of health and social services with its primary objective being to encourage members of the public to look after their health. All of the apps on the website, which are available for both iOS and Android devices for free in leading app stores, need to have passed the Foundation's own quality control process, which guarantees a safe and reliable environment for their use. In addition, doctors in PCTs can recommend the apps to their patients in their surgery, thus complementing the follow-up of the patients' condition by monitoring the data generated, which can be consulted by health care professionals and included in their clinical history, with the patient's permission. In the future, the plan is to extend access to professionals from other specialties.

After conducting various tests in the preproduction environment, the need arose to carry out a controlled pilot study with doctors and real patients to ensure the system worked correctly from a technological point of view. This document is intended to present its significant findings, generating pioneering evidence for the integration of mHealth technologies with primary care systems in a public setting [7,8].

Objectives of the Pilot Project

The overall objective of the pilot project was to test, in a real, controlled environment, the implementation of AppSalut. Specifically, the three objectives that were to be evaluated are the following: (1) that procedures corresponding to the prescription, transmission and evaluation of the data functions correctly (Figure 1), (2) users interact successfully and accept the tool, and (3) the data travels through existing pathways in accordance with international standards.

The evaluation of the pilot project is not based on clinical criteria but rather the usability and technological reliability of the intervention and its implementation in the context of primary care.

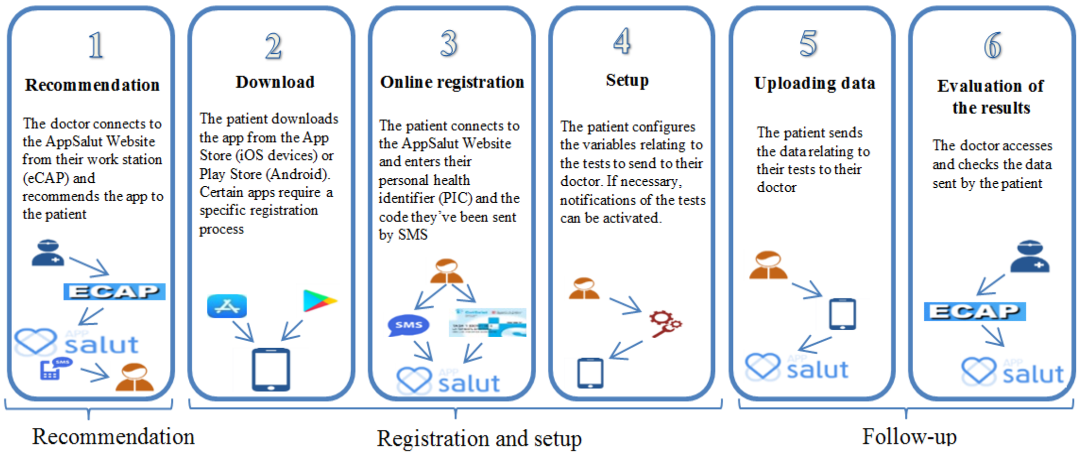

Figure 1. The AppSalut Site recommendation process.

Methods

Preliminary Design

The project was presented to the Primary Care Team (PCT) participants to encourage the involvement of doctors. Once they were recruited, together with their corresponding patients, the following three steps were taken. First, an initial consultation took place, in which the doctor was able to explain to the patient what the pilot project consisted of, provide them with the necessary documentation, and recommend the app to them. The patient was sent a SMS text message (short message service, SMS) containing an access code, and the recommendation of the app was registered on the system. Second, when the patient arrived home, they accessed the La Meva Salut (My Health, MH) Personal Health Record to view the recommendation, download the app and enter the activation code they were sent by SMS to link the app to the platform. The patient was then able to start using the app. The data was collected in a standardized manner and automatically sent to the system. Lastly, in a second visit, the patient looked at the data with their doctor on their screen. The latter was able to consult the information generated by the patient and select what to include in their Electronic Health Record.

Participant Recruitment

The agents involved in the execution of the project are presented in Table 1.

The following four PCTs participated in the study and belong to the South Metropolitan Territorial Management (province of Barcelona): Vinyets PCT (Sant Boi de Llobregat), Sant Andreu de la Barca PCT, Cubelles-Cunit PCT and Sant Ildefons PCT (Cornellà de Llobregat). For each team, the involvement of at least 5 PCT doctors and 5 patients per professional was requested and chosen at their discretion and according to their own clinical criteria. Thus, the objective recruitment population was 20 doctors and 100 patients. Patients were selected according to the following inclusion criteria: the patient's expressed their willingness to participate, and proof that they were over the age of consent and gave written authorisation. Since the object of the study was the implementation of the process rather than the evaluation of any clinical outcomes, the intervention was not assigned in a randomized manner. Consequently, potential biases (medium-advanced users of mobile technology) can be assumed to be present and caution should be exercised in the extrapolation of the results.

Mobile Apps

Three mobile apps were used (see Table 2). They were chosen for their potential in providing continuity of care for the conditions they address, and their ability to adapt to the requirements that were identified during the pilot study. The integrated apps were required to perform specific technical adaptations to conform to the specific doctor-patient context effectively. The three of them could be downloaded free-of-charge.

Duration

The planned duration was initially 3 months. However, due to the decrease in the use of the platform during the summer holidays (July and August) it was extended to 5 months from the time the PCT candidates for participation in the pilot were identified, until the last recommendation was made. The variables sent by the app continued to be recorded in November to include information from users recruited during the end of October. Thus, the period covers June 1 to November 30, 2017.

Follow-Up and Monitoring

To initiate the pilot study, presentations were organized to introduce the doctors to the project and to train them in the prescription and use of the apps. Once started, the timing of periodic follow ups was established, accompanied by training for the doctors to ensure the processes were clear and to deal with any doubts. After detecting problems in various phases of the recommendation of the apps, it was decided to occasionally assist the professionals in the prescription process and the patients in downloading, registering, and configuring the app.

Organization	Role
Fundació TIC Salut Social (ICT Social Health Foundation)	Coordinated the entire pilot phase, training the doctors, monitoring the project, dealing with any incidents which arose, and the utilization and evaluation of the results
Four PCT belonging to the South Metropolitan Territorial Management Directorate of the Catalan Health Institute	Clinicians are the users of the eCAP, the main clinical management software used by primary care clinicians in the public system
The *Dirección Asistencial* ICS (ICS Health Care Directorate)	Participated in the validation of the process and provided training to the professionals involved
The Catalan Personal Health Record *La Meva Salut* My Health (MH)	The functional and technical managers established the AppSalut Site service within MH and provided access to the participating providers in the pilot study
IN2, an app and web developer	Offered support for technological incidents

Table 1. The roles of organizations participating in the study.

App	Health indication	App description
AsmaProcare	Asthma	An app which serves as an instrument for sending information from asthma sufferers to their physician. The daily readings of *PeakFlow* measurements are introduced via the app, as well the use of any rescue medication; the data can be displayed visually in the apps' interface. In addition, the user is able to see the ongoing treatment introduced in the *backoffice* by their doctor.
ExpertSalud	Chronicity	An app that allows the monitoring of the pharmacological adherence to a treatment. It is designed to help manage the intake of medications, the setting of reminders and the monitoring of variables such as weight and glucose levels.
Sideal	Alcohol consumption	A self-help system for people with alcohol dependence that offers advice aimed both at reducing intake and abstinence and which allows monitoring both of consumption and therapeutic compliance based on the objectives that the person sets or agrees with their doctor.

Table 2. Apps used in the pilot project.

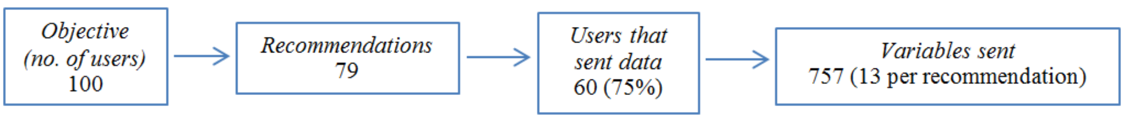

Figure 2. Participant attrition diagram.

The recommendation was made to the patient in the doctor's surgery, while the process of downloading the app, registering the patient on the platform and configuring the relevant variables was carried out in an adjoining surgery by the Foundation's staff. In this way, the most critical period within the process was reduced, where the highest rate of loss of patients was identified: when the user connects with the platform and needs to configure the variables. These follow-ups were an important aspect in the development of the project since they allowed to gain personal experience from the problems which arose and to implement corrective measures and additional training. The following Figure 2 summarizes the evolution of the project's adherence.

Results

Usage of the Instrument

A total of 32 doctors made 79 recommendations of apps to patients, representing 160% of doctors and 79% of recommendations compared to what was expected during the design of the pilot project. Of the recommendations, 75% (60/79) of patients used the app, sending a total of 757 variables to the system (Table 3). In general, the main reasons for non-use were connection errors with the platform, problems with accessing the app (incorrect configuration, failing to activate alerts and problems with the confirmation email), and dropping out (mainly due to the study coinciding with the summer holidays and loss of motivation).

The amount of prescriptions made to patients was heterogeneous along the intervention period. As shown by Figure 3, the reduction occurred from the second half of July to the first half of September, coinciding with the doctors' vacation period, bringing out one of the major design drawbacks. The aforementioned heterogeneity can also be noted by the number of recommendations made by the doctors. A first subgroup has made only one, while at the other extreme many doctors made five or more. It can be seen, therefore, that the shortfall in meeting the objective concerning patient recruitment is primarily due to the first subgroup of less-motivated doctors.

Primary care team	Physician recommendations per primary care team, n	Patients who sent data per primary care team, n (%)	Total messages sent per primary care team, n	Messages per patient per primary care team, n (%)
Cubelles-Cunit	12	10 (83)	206	21 (10.2)
Cornellà	16	12 (75)	165	14 (8.5)
St. A de la Barca	22	14 (64)	92	7 (7.6)
Sant Boi	29	24 (83)	294	12 (4.1)
Total	79	60 (75)	757	54 (7.1)

Table 3. Physician recommendations, messages, and data-uploads sent per primary care team.

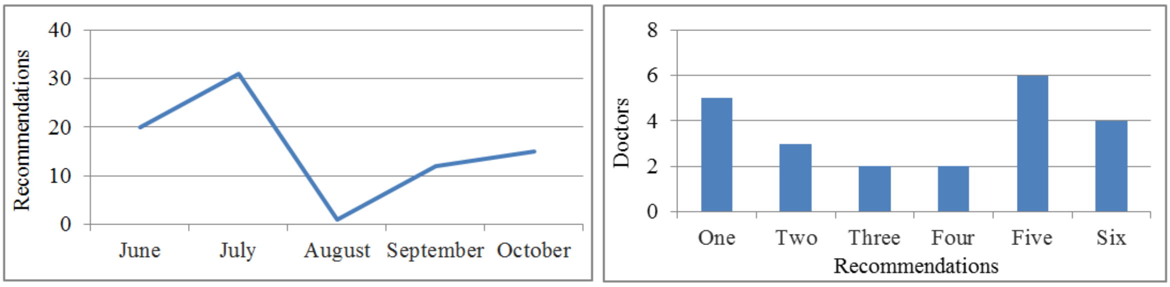

Figure 3. Monthly recommendations and number of recommendations per professional.

App	Number of patients used (n=79), n (%)
AsmaProcare	9 (11)
ExpertSalud	67 (85)
Sideal	3 (4)

Table 4. Apps use by patients.

Uploading of Data

Regarding which apps were likely to be prescribed (Table 4), ExpertSalud was the most-used by the patients (67/79, 85%). According to the results of the focus groups and the periodic follow-ups, this could be due to the full range of variables that the app can handle (glycemia, blood pressure, weight, pain, stress, pulse, dizziness). Very few patients used the AsmaProcare app (9/79, 11%), while prescription of the Sideal app was negligible (3/79, 4%).

On average, the patients uploaded data 9.6 (757/79) times per prescribed app, accounting for a total of 16 different variables. Weight was the most used (28/79, 35%) upload, followed by systolic and diastolic blood pressure variables (21/79, 26%) uploads, and heart rate (11/79, 13%) uploads. Other variables such as temperature, alcohol intake and dizziness levels were not used as much, with migraine being the least used variable. To ensure a consistent exchange of the apps' variables, the mHealth Office and the Foundation's *Oficina de Estándares e Interoperabilidad* (Standards and Interoperability Office) employed a subset of codes for mHealth variables using controlled vocabulary that guarantee their unique identification: Systematized Nomenclature of Medicine-Clinical Terms (SNOMED CT) is the reference vocabulary used in the subset, but other classifications and terminologies, such as International Statistical Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), International Statistical Classification of Diseases, Tenth Revision (ICD-10), Logical Observation Identifiers Names and Codes (LOINC), Anatomical, Therapeutic, Chemical Classification System (ATC), and International Classification of Primary Care (ICPC), were also considered and then transformed into SNOMED CT.

Usability Evaluation

Two ad-hoc case-specific questionnaires, one for doctors and one for patients who had participated in the pilot study were sent by email during the first week of November (the deadline for making new recommendations, but while data was still being sent). They were completed on a voluntary basis. A total of 17/32 (53%) responses from doctors and 30/79 (38%) from patients were received.

Doctors' Questionnaire

Information was collected from the doctors as to the app recommendation process, the use of the data, and the general characteristics of the platform.

The main ideas derived from each of these issues are described in the following. First, making a recommendation is not an easy task (since it lengthens the consultation) and the patient is not autonomous in its management: they must receive support. Second, visualizing the data is easy and is carried out before, during and after consultation with the patient, indicating the success of the integration model in patient-doctor environments.

Source	Incidence (N=34), n (%)
AsmaProcare (app)	
User training	1 (2.9)
ExpertSalud (app)	
Sign up email	6 (17.6)
Make of smartphone	2 (5.9)
AppSalut (site)	
SMS[a] code	16 (47.1)
Error connecting with platform	3 (8.8)
Problems connecting patients	6 (17.6)

[a]SMS: short message service.

Table 5. Incidences by type.

Third, with respect to the platform, the doctors would like to be able to create alerts based on the data they have received. In general, they value the usefulness of the AppSalut Site as part of the health care process (3.4, on average, on a scale of 1 to 5, 5 being "Very useful").

Patients' Questionnaires and Focus Groups

Regarding the users, the questionnaire collected information on three topics: the recommendation process, the use of the Personal Health Record, and the use of the app. In relation to the first, the patients' experience confirms the difficulties identified in linking the app with the professional's prescription. Nevertheless, the added value that is expected both from the patient's ability to use the app autonomously and from the doctor's ability to access the information is very high. With respect to My Health (MH), in spite of the difficulties patients faced in terms of access, the prescription of the app was closely associated with access to the patient's Personal Health Record (two out of three patients used it). Finally, regarding the usage of the app, patients would consider recommending it to other patients with the same medical condition and generally see it as very simple to use. In general, they rate the AppSalut Site as "very interesting" (4.5, on average, on a scale of 1 to 5).

To complement this qualitative vision, three focus groups were established (two consisting of doctors, one of patients) with a minimum of three participants, with a professional from the Foundation acting as moderator with a script and prepared questions. Both the script and the full summary of the three sessions can be found in the Multimedia Appendix 1 and Multimedia Appendix 2, confirming the ideas collected by the questionnaire's approach.

Incidents Detected During the Use of the Platform

During the pilot project, 34 incidents were registered (see Table 5). Two types stand out. First, those related to the AppSalut Site, such as the SMS being sent with a missing or invalid activation code or incidents related to connection and upload errors. Second, those related to the user's connection with the app (for example, not receiving the confirmation email to be able to use the app).

Concerning the duration of the pilot study, initially, problems were detected related to users getting lost on the platform and their access to the website, requiring a two-day halt in the prescription process. In general, incidents were detected regarding the connection and access to the AppSalut Site that will need to be reviewed during an additional technical audit.

Discussion

Principal Findings

In terms of the specific objectives, the execution of the pilot study has shown that, despite the aforementioned incidents, the platform operates continuously and safely: Therefore, it represents a significant experience in the prescription of health apps and the integration of its information in primary care practitioners' workstation in a public setting. It was observed that it is generally usable although critical issues have been identified in the user experience, which indicates room for improvement. The pilot study showed that the data travels through the established channels in an adequate manner and in accordance with international standards.

The results validate, in a controlled environment with real participants, the entire process. This includes the prescription of an app by a doctor, the patient accessing the recommendation via their Personal Health Record, download of the app by the patient from the official app stores, linking of the patient to the public platform through the app, the generation, visualization of the data on the primary care workstation, and its subsequent validation by the clinician. The following are the major findings. First, shortcomings in terms of the usability of the tool are largely associated with the user linking to the platform using the code sent by SMS, which the patient needs to activate the app. In many instances, the user registration within some of the apps is not intuitive, an issue which is also found when the patient registers with the AppSalut Site using the SMS code: some users are unable to follow the process. Once this barrier is overcome, the process is smooth in terms of sending and viewing data. Second, the patients have a very high opinion of the service while the doctors feel they need to carefully manage its implementation so as not to overload themselves: for the former it is an additional service, for the latter an added burden. Related to this, the registration process within the app and signing up with the platform is perceived as much more critical for the doctors than for the patients, who are less concerned about the difficulties. For both groups, the integration of the data generated in their usual interfaces is a key factor in its acceptance. Third, there is a steep learning curve associated with the entire process of the use of such mobile technologies; in many cases the doctors ask for additional training for the apps, both for themselves and for the patients, potentially people aged over 65, where the digital divide is present. Fourth, the recurring need for reviews and support for doctors and patients indicates that support elements are needed at least in the early stages of the intervention. Finally, in relation to the information sent by the patients, the doctors feel that it would be more useful if alerts were received within the professional work interface.

Conclusion

By way of a recommendation, three factors can be identified which would improve similar experiences. First, the choice of apps to be used is fundamental; the user's perception of the utility of the proposed tool being paramount. Second, thorough face-to-face support is vital to a smooth transition towards a more intense model of telemedicine. Last, a powerful limiting factor is the lack of control over people's ability to use the apps.

Acknowledgments

We would like to thank the clinicians and patients for their participation in the pilot study. This study was conducted with the support of the Secretary of Universities and Research of the Department of Business and Knowledge at the Generalitat de Catalunya.

Conflicts of interest

None declared.

Multimedia Appendix 1

Guide to the focus groups.

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Abbreviations

ATC: Anatomical, Therapeutic, Chemical Classification System
DHP: Digital Health Platform
ICT: information and Communication Technologies
ICPC: International Classification of Primary Care
LOINC: Logical Observation Identifiers Names and Codes
MH: My Health (Catalan Personal Health Record)
PCT: Primary Care Teams
SMS: Short Message Service
SNOMED CT: Systematized Nomenclature of Medicine–Clinical Terms CIM

2.3. A cost-minimization analysis of the interconsultation in Central Catalonia

López Seguí, F.; Franch Parella, J.; Gironès García, X.; Mendioroz Peña, J.; García Cuyàs, F.; Adroher Mas, C.; García-Altés, A.; Vidal Alaball, J. A Cost-minimization Analysis of a Medical Record-based, Store and Forward and Provider-to-provider Telemedicine Compared to Usual care in Catalonia: More Agile and Efficient, Especially for Users. International Journal of Environmental Research and Public Health 2020

A cost-minimization analysis of a medical record-based, store and forward and provider-to-provider telemedicine compared to usual care in Catalonia: more agile and efficient, especially for users

Abstract

Background: Telemedicine (interconsultation between primary and hospital care teams) has been operating in the counties of Central Catalonia Bages, Moianès and Berguedà since 2011 in the specialties of teledermatology, teleulcers, teleophthalmology and teleaudiometries. For the period until the end of 2019, a total of 52,198 visits have been recorded.

Objective: To analyse the differential costs between telemedicine and usual care in a semi-urban environment.

Methodology: A cost-minimization evaluation, including direct and indirect costs from a societal perspective, distinguishing healthcare and user's costs, within a three-month period.

Results: Telemedicine saved € 780,397 over the period analysed. A differential cost favourable to telemedicine of about € 15/visit has been observed, the patient being the largest beneficiary of this saving (by 85%) in terms of shorter waiting times and travel costs. From the healthcare system perspective, moving the time spent in a hospital care consultation to primary care is efficient in terms of the total time devoted per patient. In social terms and in this context, telemedicine is more efficient than usual care.

Conclusion: Users' saving of time in terms of consultation and travel is the main driver of interconsultation between primary and hospital care savings in a semi-urban context. The telemedicine service is also economically favourable for the healthcare system, enabling it to provide a more agile service, which also benefits the healthcare professionals.

Keywords: cost analysis, health technology assessment, provider-to-provider telemedicine, telehealth, economic analysis

Introduction

Telemedicine nowadays coexists alongside conventional healthcare in most healthcare systems [1]. Although systematic reviews of its economic impact suggest that, for the time being, it is not suited to a widespread implementation in all specialties and contexts [2,3], recent studies suggest it is cost-effective in fields such as emergency medicine, cardiology, the management of diabetes and ophthalmology [4-10, 17].

In Catalonia, an integration of the health information systems between primary care and specialized care allows for a fluid telemedicine-based case management. This implies relatively low coordination costs among different health specialties and incentivises the use of these tools by health providers. Furthermore, the availability of information on healthcare activity provides an excellent opportunity to evaluate its impacts. To this end, this study case includes four telemedicine specialties (teledermatology, teleulcers, teleophthalmogoly and teleaudiometries) which are currently conducted in the Catalan public healthcare system Central Catalonia Health Region. This includes the counties of Bages, Moianès and Berguedà, located in a large, mainly rural area, which also includes two major cities (Manresa and Berga) with an overall population of approximately 230,000 inhabitants.

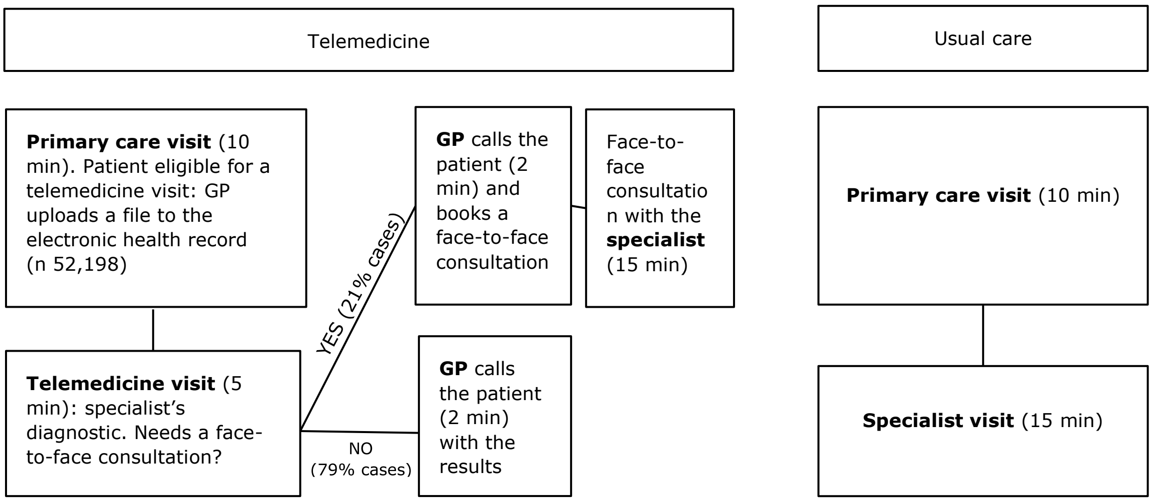
A cost-minimization analysis performed in the same setting for the specific case of teledermatology [11] showed social savings of approximately €11.4 per visit, which have an impact specially on the users (77% of the total amount saved) rather than the healthcare system (23%). This is due to the size of the reduction in the commuting time and travel costs, which is especially significant in rural settings, a thesis which is backed up by subsequent research [12]. Nevertheless, the study evaluated a short time period (teledermatology in 2016) and did not take into account other indirect costs such as the time spent by caregivers. In this context, the objective of the study is to broaden evidence on the economic impact of telemedicine with respect to usual care including other types of telemedicine (teleulcers, teleophthalmology and teleaudiometries) using a cost-minimization analysis from a societal perspective, including all direct and indirect costs feasible and significant.

Methodology

Service description

The four studied telemedicine programs all operate in a similar manner: the primary care physician or nurse (salaried staff employed by the Catalan public healthcare system) uploads a file (such as a photograph) to the patient's electronic health record together with their clinical notes; hospital specialists access the patient's electronic health record, view the images and suggest treatment or an action plan; the primary care physician or nurse reviews the instructions and makes a phone call to the patient to give them the results of the consultation; if the specialist has any doubts, they can ask the primary care professional to arrange a face-to-face consultation with the patient (Figure 1). In other words, we can say that it is a medical record-based, store and forward and provider-to-provider asynchronous telemedicine between primary and hospital care. The Catalan healthcare system, which provides a publicly financed universal health coverage, is free at the point of access thus no fee is charged for the neither the face-to-face visit nor the telemedicine service. We will assume that a telemedicine consultation avoids a face-to-face referral if it does not result in a referral for the same matter within the following 3 months. It has been shown that this telemedicine setting reduces waiting lists, while improving the access to GPs [13].

Figure 1: Patient flow: telemedicine vs. usual care.



Study type

A cost-minimization analysis was carried out, within a three-month period, using a societal perspective. Direct costs (healthcare costs corresponding to time spent by professionals and users during visits and travel expenses by users) and indirect costs (patient and caregiver's time) were included. No staff training or equipment costs were included (practitioners used pre-existing devices), since they were not subject to the interventions analysed. The cost estimate is based on 2019, a year which showed a higher number of telemedicine visits. A sensitivity analysis was carried out increasing the baseline costs. Calculations were performed using a Google Drive spreadsheet.

Direct costs

The Catalan Institute of Health provided anonymized individual data regarding all 52,198 telemedicine consultation services performed during the period November 2011 - November 2019. This dataset contains information on a case-by-case basis on the source and destination of every type of telemedicine service and whether it avoided a subsequent face-to-face visit or not. As Table 1 shows, all telemedicine services result in high face-to-face savings, ranging from 72% to 88% of the queries received.

In order to calculate the derived potential societal savings, differential costs attributable to the time spent by practitioners and citizens using telemedicine and usual care have been taken into account. From the healthcare system point of view, the saving of the intervention is based on the reduction of case management time: whereas in usual care the time spent on a face-to-face visit with a hospital care professional is 15 minutes, it is calculated that telematic monitoring of the case reduces the time to 5 minutes, redirecting the case back to the primary care professional, who calls the patient for approximately 2 minutes and closes the case, if applicable. If the specialist has any doubts, they can ask the primary care professional to book the patient for a face-to-face consultation (15 minutes). It has been taken into account that, although in the teledermatology, teleophthalmology and teleaudiometry services a primary care doctor is the one who makes the referral, in the case of teleulcers a (primary and hospital care) nurse reviews the images and sends a reply. Baseline wages are used, according to standard labour agreements, for medical and nursing professionals in primary and hospital care. Travel costs (private car expenses) are calculated using the average travel distance (the methodology is described below) and the baseline price per kilometer.

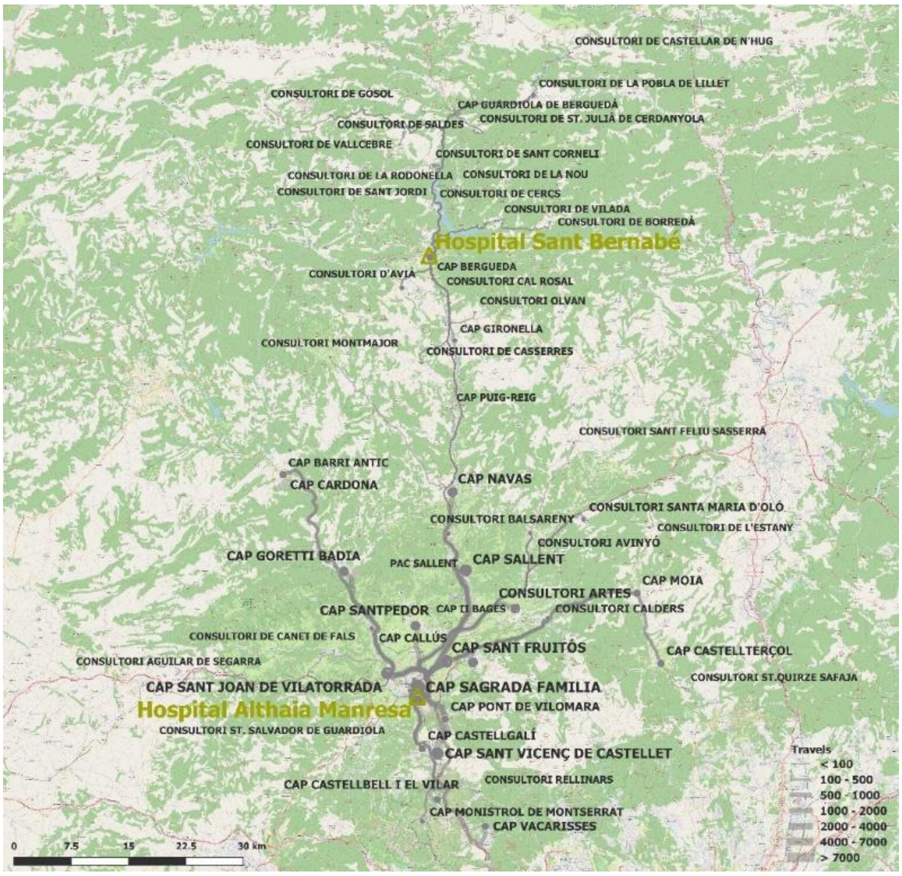
Table 1: Number of telemedicine visits and % of face-to-face visits saved, per type.

Type of telemedicine	**Number of visits**	**Face-to-face visits saved (%)**
Teledermatology	40,658	77.7
Teleophthalmology	1,180	72.1
Teleaudiometries	9,823	86.2
Teleulcers	537	88.5
*Total (*weighted average*)*	*52,198*	*(79.3)*

Indirect costs

Productive time (commuting to the hospital) lost by patients and caregivers was considered: the user also benefits from greater agility in the resolution of the case, reducing their waiting time, and also in terms of travel time to a hospital consultation (Hospitals in Manresa and Berga). Employing the methodology used by Vidal-Alaball et al. 2019 [13], through the combination of R 3.6.1 software, a Google Maps API and the information from each of the user's PCT (as a proxy for the user's place of residence) together with the referral hospital, a very accurate calculation of the total number of kilometers and time of journeys saved by the intervention was obtained (Figure 2). Therefore, the sample saved 893,820 kilometers (21.58 km per case, for the round trip) and 16,812 hours (25 minutes per case) of travel. The costs to users (patient and caregiver) have been calculated by multiplying travel and consultation time by the average salary/hour.

Figure 2: Origin and destination (either Hospital Sant Bernabé in Berga or Althaia Xarxa Assistencial Universitària in Manresa) of telemedicine visits avoided. The thickness of the line corresponds to the number of journeys saved.



Also, according to an aggregate analysis of the users' profile, it can be observed that the average age of a telemedicine service user is 52, with a standard deviation of 23, suggesting the heterogeneity of the beneficiary profile. If we assume that people aged over 65 (34% of the total sample) and under 16 (8%) require the company of a caregiver during their visits, this means that we have to add the indirect impact in terms of opportunity costs of the time spent by caregivers in 42% of the cases analysed.

The nature of each type of cost is shown in Table 2.

Table 2: Direct and indirect costs, for users and for the healthcare system.

	Direct costs	Indirect costs
Users	Travel costs	Time spent by caregivers Travel time
Healthcare system	GP's time Nurse's time	-

Finally, Table 3 shows the parameters which have been considered when making calculations and their corresponding sources: the hourly wages of professionals, the price per kilometer, the opportunity cost of the user, the total number of visits (saved), consultation time with the specialist with and without telemedicine, the primary care professional's phone call time, and average time and distance for users. The results are shown for both perspectives (healthcare system and user).

Table 3: Calculation parameters.

	Concept	Amount	Source
Costs (€)	Wage/h primary care doctor	24.60	ICS [14]
	Wage/h primary care nurse	17.68	
	Wage/h hospital doctor	22.46	UCH [15]
	Wage/h hospital nurse	16.53	
	Travel cost per km	0.25*	Own
	Average time value (patient and caregiver)	13.36	SAIT [16]
Variables observed	Total number of visits	52,198	Own
	Number of visits saved	41,402	
	Teleulcers number of visits	537	
	Teleulcers number of visits saved	472	
	Not teleulcers number of visits	51,661	
	Not teleulcers number of visits saved	40,930	
	Minutes with specialist in face-to-face visit	15*	
	Minutes with specialist in teleconsultation	5*	
	Minutes in primary care visit	2*	
	Average travel distance km	21.58	R + Google API
	Average travel time	0.4	R + Google API

*For the comparability between studies, the baseline scenario takes the same parameter as in Vidal-Alaball et al. [11].

Results

Table 4 shows the results of calculating the societal savings (distinguishing between those of the healthcare system and of the users) from the use of telemedicine in relation to usual care. While the cost of making phone calls is exclusive to the telemedicine program (€ 42,675), there is a reduction in the time spent by hospital staff: despite the fact that 21% result in a face-to-face visit, and that the salary per hour is higher in the context of primary care than in hospital care, the consultation time of 79% of cases is reduced by 8 minutes, implying a saving in relation to usual care, where all visits are face to face and 15 minutes, for a professional time equivalent to € 154, 542 for the sample under analysis.

Table 4. Differential costs between telemedicine and usual care (in €).

	Concept	Telemedicine	Usual care	Difference
Healthcare system's costs	Primary care staff phone call	42,675		42,675
	Hospital staff	137,805	292,347	- 154,542
Users' costs (patient and caregiver)	Consultation time	62,240	247,565	- 185,325
	Travel time	962	318,957	- 317,995
	Travel cost (private car)	58,244	223,455	- 165,211
	Total	301,926	1,082,324	- 780,397
	Total per patient	5.78	20.73	- 14.95

Regarding patients, while also taking into account cases where telemedicine is ineffective in avoiding a face-to-face visit, there is a saving on consultation and travel time of € 185,325 and € 317,995 respectively. These two parameters take into account the assumption that 42% of the cases had to be accompanied in face-to-face visits. In terms of fuel, the difference between the cost of telemedicine and usual care is € 165,211, being the result of substracting the product of the average travel distance per case (21 km) by the cost/km (€ 0.25) by the number of cases that have avoided a face-to-face visit (41,402, totalling € 223,455) and the equivalent cost from telemedicine visits that have not avoided a face-to-face visit (€ 58,244). Thus, the total of the costs and differential savings for the different types of telemedicine is approximately € 780,397 (€ 15 saving per visit).

Sensitivity analysis: an even more favourable scenario for telemedicine

In order to comparatively evaluate the results, a maximum estimate of the sensitivity analysis is included by varying some of the assumptions (Table 5). This second scenario increases the costs included in Table 3 by 20%: the patient travel time and that of their possible companion (assuming that the actual time is not wholly shown in Google Maps, but that there are transaction costs derived from going to pick up the car, looking for a car park, attending the consultation or waiting for the patient's turn), the travel cost (measured in €/km, assuming that it could be increased with respect to the evaluation performed for teledermatology [11]) and the hourly wages of medical professionals (assuming that the real cost may be closer to the company cost, rather than the actual remuneration received by the health professionals). The results of this scenario show that the savings increase by approximately 8%, as much as € 17/visit and continue to be mostly favourable for the user (85%). A sensitivity analysis was not performed on the opposite scenario, assuming that the calculation of time and distance savings made using Google Maps is in itself minimum.

Table 5. Sensitivity analysis: 20% increase in costs. Main results (€).

	Concept	Telemedicine	Usual care	Difference
Healthcare system costs	Primary care staff phone call	51,210		51,210
	Hospital staff	165,366	350,816	- 185,451
User's costs	Patient: consultation time	50,221	247,565	- 197,344
	Patient: travel time	1,154	382,748	- 381,594
	Travel cost (private car)	69,893	268,146	-198,253
	Total	337,844	1,249,275	- 911,431
	Total per patient	6.47	23,93	- 17.46

Discussion

Conclusions

The results show that telemedicine minimizes the costs of the two agents included in the analysis (the user and the healthcare system): both from one or the other perspective, telemedicine is better than usual care from an economic point of view. However, it is observed that from the € 14.95 saving per visit, approximately 85% benefit the patient, showing that this kind of intervention is especially convenient for the user, particularly for the time saving which it offers.

In relation to the study with 2016 data

The study concludes that, in the context studied, telemedicine is an unequivocally preferable option to usual care, from an economic point of view. The strength of this diagnosis is similar to that derived from the analysis performed with 2016 data for the specific case of teledermatology: the result of including other specialties (teleulcers, teleophthalmology and teleaudiometries), lengthening the time period (by using the complete sample available) and adding the indirect cost approach of the caregiver results in savings per visit 35% above the base case studied by Vidal Alaball et al*.* with 2016 data [11] (Table 6). We note that, once caregivers' opportunity costs are introduced, the most important differential corresponds precisely to the calculation of the cost in time of users. The similarity of results between the different type of costs reflects the robustness of the methodology used.

Sensitive variables

The magnitude of the result is highly sensitive to the parameter corresponding to the opportunity cost (lost productivity) of the user and this has been calculated homogeneously among the different beneficiary profiles (minors, of working-age and retirees): although an eventual differential calculation by profile would not change the results, it would far better approximate the representative total of the savings. It should be borne in mind that in contexts with higher labour productivity of both professionals and users, the results of the analysis would be much more favourable to telemedicine.

Table 6. Differential costs per visit. Comparison between studies.

Type of costs		Previous study [11] (€)	Baseline scenario (€)	Previous study [11] (% of total)	Baseline scenario (% of total)
Healthcare system costs	Primary care staff	0.77	0.82	22.60	14.33
	Hospital staff	- 3.42	- 2.96		
User’s costs	Time	- 6.31	- 9.64	77.40	85.67
	Travel cost	- 2.76	- 3.17		
	Total	- 11.71	- 14.95	100	100

With regard to the extrapolation of these conclusions and with the “travel time” factor, it is worth keeping in mind that the study was performed in a mostly rural and semirural setting. The average distance per journey may be higher than in urban settings although it is not clear if the journey time would be higher (as moving within a city is much slower). Whatever the case, the results show that both factors (travel cost and time lost) are sufficient to reach the same conclusion: even if telemedicine did not save on travel costs (being “zero kilometer”) if would be cost-effective, and even if it did not save anything in terms of time (for the user and the healthcare system) it would also be cost-effective.

As to the assumption that patients travel by car, it is reasonable to assume that some of them use public transport. If we consider this possibility, telemedicine savings would be even higher since in rural settings, where the frequency of public transport is very low, the potential savings in terms of travel costs (using public transport instead of private transport) would clearly be far outweighed by more travel time (with and without waiting time): in the context involved in the study, almost devoid of a railway network (except in the south of the city of Manresa), it is unlikely that the bus is faster than private transport.

Factors not included in the analysis

While it is true that this assessment includes the differential essential elements between the two alternatives analysed, it does not include objective or easily monetizable intangible factors such as the users’ and professionals’ satisfaction with the service or the improved management of cases in function of their clinical severity. This improvement in care management could reduce waiting lists to the access of GPs, one of the biggest problems in the Catalan healthcare system. In this context, telemedicine allows for better allocation of care time according to the complexity of the case: future lines of research ought to quantify these factors, which are complementary but key in order to evaluate the service’s effectiveness.

In addition, the type of analysis performed assumes that clinical effectiveness is equivalent: although a time period which includes aspects strictly related to management seems sufficient to make a good diagnosis, as is the case, and despite the complexity of the information which would be needed, we ought to try to ensure the hypothesis of equivalence in health impact and add any significant and differential costs which go beyond and which can be calculated in a rigorous manner.

It needs to be taken into account that as doctors are salaried, their increased productivity does not imply a direct translation into the healthcare provider's income account: instead, the freer the practitioners are, the less amount of practitioners the healthcare provider will need to hire. In other words: savings might not rather show up in the short term but in the mid-term.

It should also be considered that the increased easiness to make a referral might have incentived GPs to use the interconsultation as a second opinion tool to support the diagnosis of patients they would normally have treated. This might have increased the ratio of saved face-to-face visits.

Finally, it should be mentioned that the study also assumed that the differential cost of expenses such as cameras or clinical software is zero, since this was the case, but in the case of introducing this service from scratch in another context these costs would have to be taken into account. In any case, the magnitude of the savings made by the service makes it unlikely that including them could significantly alter the results of the analysis.

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2.4. Machine Learning to assess the impact of teleconsultation on face-to-face visits

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Teleconsultations between Patients and Healthcare Professionals in Primary Care in Catalonia: The Evaluation of Text Classification Algorithms Using Supervised Machine Learning

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Abstract

Background: The primary care service in Catalonia has operated an asynchronous teleconsulting service between GPs and patients since 2015 (eConsulta), which has generated some 500,000 messages. New developments in Big Data analysis tools, particularly those involving natural language, can be used to accurately and systematically evaluate the impact of the service.

Objective: The study was intended to assess the predictive potential of eConsulta messages through different combinations of vector representation of text and machine learning algorithms and to evaluate their performance.

Methodology: Twenty machine learning algorithms (based on five types of algorithms and four text representation techniques) were trained using a sample of 3559 messages (169,102 words) corresponding to 2268 teleconsultations (1.57 messages per teleconsultation) in order to predict the three variables of interest (avoiding the need for a face-to-face visit, increased demand and type of use of the teleconsultation). The performance

of the various combinations was measured in terms of precision, sensitivity, F-value and the ROC curve.
Results: The best-trained algorithms are generally effective, proving themselves to be more robust when approximating the two binary variables "avoiding the need of a face-to-face visit" and "increased demand" (precision = 0.98 and 0.97, respectively) rather than the variable "type of query" (precision = 0.48).

Conclusion: To the best of our knowledge, this study is the first to investigate a machine learning strategy for text classification using primary care teleconsultation datasets. The study illustrates the possible capacities of text analysis using artificial intelligence. The development of a robust text classification tool could be feasible by validating it with more data, making it potentially more useful for decision support for health professionals.

Keywords: machine learning; teleconsultation; primary care; remote consultation; classification

Introduction

eConsulta is an asynchronous teleconsultation service between patients and GPs as part of the electronic health records of the public primary healthcare system of Catalonia. In operation since the end of 2015, this secure messaging service was designed to complement face-to-face consultations with primary healthcare teams (PHT). It was gradually implemented up until 2017, when the service became available to every PHT; currently, all of them have used this tool at least once.

An earlier study analysed the reasons why patients sought a consultation, which resulted in a patient–doctor interaction, as well as the subjective perception of the GP if they avoided a face-to-face visit or if it led to a consultation which otherwise would not have occurred, by means of a retrospective review of text messages relating to each case [1]. The results show there was a broad consensus among GPs that eConsulta has the potential to resolve patient queries (avoiding the need for a face-to-face visit in 88% of cases) for every type of consultation. In addition, GPs declared that ease of access led to an increase in demand (queries which otherwise would not have been made) in 28% of cases. Therefore, the possibility of eConsulta replacing a conventional appointment stands at between 88% and 63% (88% × (1 − 28%)). The most common use of e-consultation was for the management of test results (35%), clinical enquiries (16%) and the management of repeat prescriptions (12%).

Technology offers new possibilities for policy evaluation in conjunction with the aforementioned classical approaches. Artificial intelligence tools are already widely used in the field of healthcare in areas such as the prediction and management of depression, voice recognition for people with speech impediments, the detection of changes in the biopsychosocial status of patients with multiple morbidities, stress control, the treatment of phantom limb pain, smoking cessation, personalized nutrition by prediction of glycaemic response, to try to detect signs of depression and in particular for reading medical images [2,3,4,5,6]. The generation of data implies a huge potential for the impact assessment of these interventions with new analytical tools.

The classification of texts in the medical field has also been used to conduct a review of influenza detection and prediction through social networking sites [7,8,9] and in the analysis of texts from internet forums [10,11]. More specifically, in the framework of teleconsultations, a US-based study used machine learning to annotate 3000 secure message threads involving patients with diabetes and clinical teams according to whether they contained patient-reported hypoglycaemia incidents [12]. As far as the authors are aware, no study has looked into the development of a text classification algorithm in the context of teleconsultations between patients and primary care physicians.

The present study aims to evaluate specific text classification algorithms for eConsulta messages and to validate their predictive potential. The algorithms have been trained using a vector representation of text from the body of the message and the three variable annotations that primary healthcare professionals in Central Catalonia used in a previous study: avoiding the need for a face-to-face visit, increased demand and type of use of the teleconsultation [1]. Our study represents an exhaustive exploratory analysis of text classification algorithms of teleconsultation messages between GPs and patients that can provide useful information for future research and a potential use for decision support in healthcare.

Methodology

Data Acquisition

The teleconsultations that had previously been classified that were used as the basis for training the algorithm are those which were acquired in the study by a previous study (López) (Table 1). They are part of the health records of the *Gerència Territorial de la Catalunya Central* of the *Institut Català de la Salut* covering the period from when the tool was first used until the date of its extraction for analysis purposes (8 April 2016 to 18 August 2018). Message deidentification was performed by substituting all possible names contained in the Statistical Institute of Catalonia database [13] with a common token and removing all other personal attributes. The classification method used for the conversations is described and justified by López et al. 2019: Every healthcare professional who received an eConsulta labelled it according to whether, in their opinion, it avoided the need for a face-to-face consultation, led to an increased demand and by type of teleconsultation (Appendix A.1). These results of this annotation, with the corresponding messages, were used to train the text classification model using the three variables previously mentioned (Table 2).

Most of the data were received with a tabular arrangement, and the texts and their labels were in different files that were merged according to the Conversation ID. The data cleaning was a multi-step process. Regarding the text: First, all the tokens of anonymized names were changed to a standard name of the country "Juan". The title was merged with the body of the message, adding the token "xxti" before the title and "tixx" after the title;

that way we would not lose the information that this was the title. The texts were all converted to lowercase, and we extracted the length (in words and in characters) of every message to use as extra independent variables. As additional variables, the day of the month and time of the day were extracted from the date of the message.

Table 1. Data recorded by the teleconsulting system.

Conversation Title	**Conversation ID**	**Message ID**	**From**	**To**	**Message**	**Files Attached?**
Travelling to Australia	C1	M1	Mr. John Patient	Ms. Jane Doctor	Dear doctor, I'm travelling to Australia. Do I need to have any vaccinations?	No
		M2	Ms. Jane Doctor	Mr. John Patient	Hi, vaccination is required for travel to Australia	No

Table 2. Annotation by the GP.

Conversation ID	**Face-to-Face Visit Avoided?**	**Increased Demand?**	**Type of Visit**
C1	Yes	No	6 (Vaccinations)

Vector Representation of Text in eConsulta Messages

The emails needed to be represented in some way in order to use them as input for the models. A common practice in machine learning is the vector representation of words. These vectors capture hidden information about the language, such as word analogies and semantics, and improve the performance of text classifiers.

Four techniques have been used to generate the vector representation of texts. The Bag of Words (BoW) approach counts the number of times pairs of words appear in each document. The document is represented as a vector of a finite vocabulary. The Term Frequency–Inverse Document Frequency (TF–IDF) method assigns paired words a weight depending on the number of times they appear in a particular document (the Term Frequency), while discounting its frequency in other documents (Inverse Document Frequency): The more documents a word appears in, the less valuable that word is as a signal to differentiate any given document. Word2Vec is a two-layered neuronal network that trains and processes text. Its input is a corpus of text and its output is a set of vectors for the words in the corpus, with words represented by numbers. The initial vector assigned to a word cannot be used to accurately predict its context, meaning its components must be adjusted (trained) through the contexts in which they are found. In this way, repeating the process for each word, word vectors with similar contexts end up in nearby vector spaces. Fasttext [14] is used to obtain word2vec vectors. Finally, the objective of Doc2vec is to create a numerical representation of a document, regardless of its length. This approach represents each document by a dense vector, which learns to predict the words in the document [15]. In all cases, before carrying out the vectorization of the texts, these were first tokenized and any stop-words eliminated (those which are taken to have no meaning in their own right, such as articles, pronouns or prepositions).

In each instance, the vectors were enriched by supplementing them with similar texts in Catalan and Spanish [16]. The external data used to enrich the corpus were models of interactions extracted from online databases with colloquial language similar to that used in eConsulta. Where augmented BOW, TF-IDF and Word2Vec were used, word and character length and word density were also used as predictor variables.

Training and Testing AI Algorithms

The task addressed in this study is a multiclass classification with respect to the type of visit and two binary classifications for the other two variables (avoiding visit and increased demand). For each text vector representation algorithm five different algorithms were implemented: Random Forest, Gradient Boosting (lightGBM), Fasttext, Multinomial Naive Bayes and Naive Bayes Complement [17]. Bayesian text classifiers are the most standard algorithms in this setting. A convolutional neural network was also used using the augmented Word2vec vectors. We tested the performance of the algorithms through a stratified 10-fold cross-validation: During 10 iterations/trainings, 9 divisions served as learning and 1 as a test.

The coefficients of interest to evaluate the goodness of the algorithms were precision (the fraction of relevant instances between the retrieved instances/proportion of correct predictions of the total of all predicted cases) and sensitivity (the number of correct classifications for the positive class "true positive"). It was decided not to use the "accuracy" coefficient since it is a metric that, given an unbalanced dataset like the one under investigation, can result in a very high score in spite of the fact that the classifier works poorly, since it assesses the number of total hits without taking into account whether most of the data is of the same class. The F value is used to determine a weighted single value of accuracy and completeness. The diagnostic value is assessed by means of the ROC curve. The goodness-of-fit of all the coefficients is represented as a value between 0 and 1.

Python 3.7 and the following libraries were used for the algorithm training: numpy [18], matplotlib [19], seaborn [20], altair [21], scikit-learn [22], pandas [23], gensim [24], nltk [25], fasttext [14], pytorch [26] and lightGBM [27]. The majority of the code was carried out on Jupyter Notebooks [28].

Ethical Considerations

The study was approved by the Ethical Committee for Clinical Research at the Foundation University Institute for Primary Health Care Research Jordi Gol and Gurina, registration number P19/096-P, and carried out in accordance with the Declaration of Helsinki [29].

Results

In order to assess the predictive potential of eConsulta messages regarding the three variables of interest, we first aimed to identify the best combination of algorithms. A total of 3559 messages (169,102 words) corresponding to 2268 teleconsultations (1.57 messages per teleconsultation) were analysed in a framework of 20 different combinations of vector representation of text and machine learning algorithms (Table 3). We assessed the performance of the combinations of algorithms though a stratified 10-fold cross-validation analysis. Figure 1 shows the performance of the most stable algorithm (best metrics, in general) according to the predictor variable.

Figure 1. Performance metrics of algorithms.

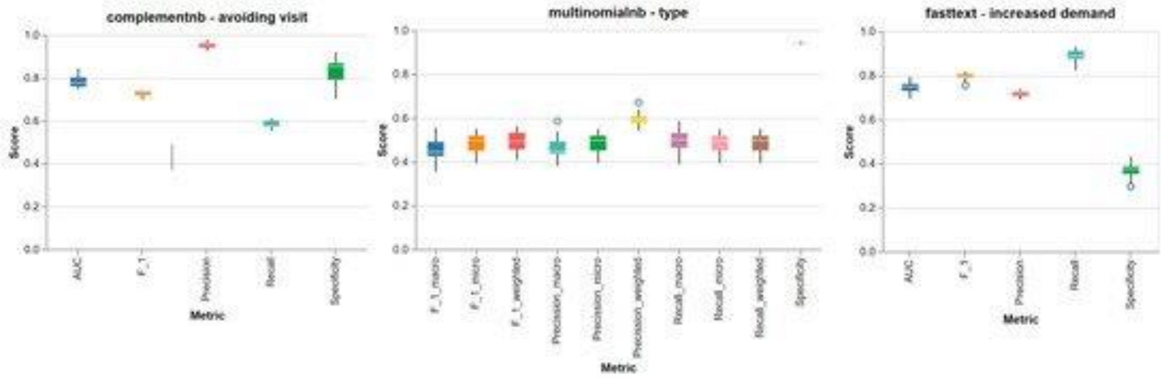

Table 3. Text representations and algorithms used.

Text Representations	Algorithms
BoW	Random Forest
TF–IDF	Gradient Boosting (lightGBM)
Word2Vec	Fasttext
Doc2Vec	Multinomial Naive Bayes
	Complement Naive Bayes

Specific combinations of algorithms per variable generally perform very well. Table 4 shows the evaluation metrics (mean + standard deviation of the 10 iterations) of the combination of algorithm and numerical representation of the text which has a better performance for each target variable. For all of the cases, the vectors obtained directly from the original texts have been more useful than those enriched with external texts. Table 4 shows that algorithms are generally effective, showing they are better when approximating the two binary variables (avoiding the need for a face-to-face visit, increased demand) than the variable "type of query". Thus, eConsulta's classifiers have a promising and robust predictive value, especially for binary variables.

Table 4. Results of the best algorithm/text representation combination, according to the variable to be approximated. Average (SD) of the 10 iterations.

Variable	Precision	Recall	F1	Roc_AUC
Avoiding the need of a face-to-face visit	Random Forest TF-IDF 0.98 (0.026)	FastText Word2Vec 0.99 (0.005)	FastText Word2Vec 0.92 (0.004)	ComplementNB TF-IDF 0.79 (0.032)
Increased demand	Random Forest TF-IDF 0.97 (0.057)	FastText Word2Vec 0.89 (0.029)	FastText Word2Vec 0.79 (0.018)	FastText Word2Vec 0.75 (0.031)
Type of use of the teleconsultation (micro averaged score)	MultinomialNB BOW 0.48 (0.049)	MultinomialNB BOW 0.48 (0.049)	MultinomialNB BOW 0.48 (0.049)	

As a whole, the results illustrate eConsulta's algorithm classifiers potential predictive value and provide a valuable insight into the implementation of AI methodologies for healthcare teleconsultation.

Discussion

Limitations

Several limitations apply to this study and the results must be understood in light of these shortcomings. First, our classifier is restricted to one dataset and the training set was relatively small. Although the study used all the available information, more data is needed to generalize the model and avoid overfitting.

The amount of data with which the algorithms were tested is especially relevant in the case of trying to calculate the variable "type of message", since the number of types which contain the classification [13], meaning the quantity of messages of each with which the classification algorithm has been trained, is minimal, thus diminishing its predictive capacity. This may have had implications to our approach and subsequent results. What is required is not only more messages, they must also contain as much information as possible. Validating the algorithm requires a replication of the proposed methodology with a larger data set, together with the analysis of subgroups. Likewise, the goodness of fit of the results may be caused by overfitting: The model explains this set of data well, but could show weaknesses when generalizing to others, limiting its potential for extrapolation. Because of that, this study includes exhaustive detail of the methodology used in order that it can be replicated.

Second, an error analysis was not conducted. This analysis might have helped us to understand why certain posts where misclassified or classified correctly.

Using complex mathematical models makes it difficult to explain why some work better than others. The vectors would need to be evaluated at a lower level in order to have a better idea as to which characteristics redirect the model towards one decision or another. This analysis is of interest for future applications of these techniques on a larger scale or for applications related to medical practice.

Conclusions

In Catalonia, the number of conversations and messages now stand at approximately 370,000 and 500,000, respectively. Applying a classification algorithm like the one proposed here would help us understand the nature of the conversations and their impact in real time. Future research should evaluate the use of automation (to send a diagnostic test, generate an alert or "thank you" and close the case) as a tool for decision support for healthcare professionals to improve the management of clinical cases and to save GPs time. Natural Language Processing approaches should further analyse the content of the teleconsultations and proactively offer clinicians agile resources to deal with the cases.

This article has shown that the implementation of an algorithm for the prediction of factors such as a reduction in the number of face-to-face visits, induced demand or type of consultation is technically feasible and potentially useful in the context of service planning, management of the demand and evaluation. This study presents a combination of algorithms based on machine learning and a more efficient representation of vectors for this type of data. This study is an initial exploration into the potential of teleconsultation and the promising use of artificial intelligence for the evaluation of digital health interventions.

Author contributions

Conceptualization, F.L.S., J.V.-A.; methodology, R.A.E.A., G.d.M.; software, R.A.E.A., G.d.M., S.W.; validation, F.L.S., R.A.E.A., G.d.M., A.G.-A., F.G.C., S.W., M.S.C., J.V.-A.; formal analysis, F.L.S., R.A.E.A., J.V.-A.; investigation, F.L.S., R.A.E.A., G.d.M., S.W., J.V.-A.; resources, F.L.S., J.V.-A.; data curation, R.A.E.A.; writing—original draft preparation, F.L.S., J.V.-A.; writing—review and editing, F.L.S., R.A.E.A., G.d.M., A.G.-A., F.G.C., S.W., J.V.-A.; visualization, F.L.S., A.G.-A., F.G.C., S.W., M.S.C., J.V.-A.; supervision, F.L.S., A.G.-A., F.G.C., M.S.C., J.V.-A.; project administration, F.L.S.; funding acquisition, F.L.S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of interest

The authors declare no conflict of interest.

Abbreviations

GP	General Practitioner
BOW	Bag of Words
TF-IDF	Term Frequency—Inverse Document Frequency
ROC	Receiver Operating Characteristics

Appendix

Reasons for using eConsulta

Administrative

1 Management of test results

o The patient provides the results of tests carried out in an external centre in order that they are recorded in their medical history.
o The GP provides the results of tests with normal results.
o The GP deals with questions related to tests requested by the patient.
o The GP requests tests after conducting a follow-up teleconsultation.

2 Temporary disability management

o The patient communicates changes to their health related to an upcoming temporary disability.
o The GP tracks the progress of a temporary disability in conjunction with face-to-face visits.

3 Management of visits/referrals

o The patient has an enquiry which the GP thinks ought to be dealt with by a specialist and refers them. They can also report incidents resulting from any referrals made.
o The GP resolves incidents relating to the timing of visits.
o The GP cancels visits from other clinicians in cases in which the problem has been resolved following completion of the e-consultation.
o Validation of appointments with other specialists where the citizen needs more information about the motivation of the appointment.

4 Request for a clinical report/sick-note

o The patient asks for a report/sick-note while consulting their medical history.
o The GP asks the patient for more information in order to prepare the report.

5 Repeat prescriptions

o The patient asks for their prescription to be updated if it has been modified by an external specialist, either because they do not use it or because it has expired.
o The GP warns the patient that their prescription is about to expire and updates it.
o The GP cancels an unnecessary prescription following an e-consultation.

6 Vaccinations

o Updates of immunization schedules and general enquiries regarding vaccinations.
o Questions concerning vaccinations for travel overseas.

7 Other administrative issues: Any administrative procedure which can be resolved without being physically present.

Medical

8 Medical enquiries: The patient has a question about their health that can be resolved without a physical examination. They can also attach photographs to accompany the description.

9 Issues regarding medicines: the patient asks a question about a prescription.

10 Questions regarding anticoagulants and dosage.

Others

11 Messages sent in error: The patient made a mistake.

12 Other.

13 Test messages.

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3. Discussion

3.1. Conclusions

3.1.1. With respect to the general objective

The general objective of this doctoral thesis is to evaluate digital health services within the Catalan public health system. The following is a summary of the main lessons learnt from the three articles included in the compendium.

In relation to the app-telemonitoring in primary care

The study *The Prescription of Mobile Apps by Primary Care Teams: A Pilot Project in Catalonia* (section 0) is proof of the high level of technological deployment, as far back as 2018, of mobile-based data integration for decision making in the Catalan primary care environment. The text aims to evaluate the implementation of the pilot project (it shows the technical feasibility of the application prescription circuit, the reasonable usability of the system for users and the correct transmission of information using international health interoperability standards) and serves as an acknowledgement of the main lessons learnt. In summary, it is observed that:

- Users are ready and willing to participate more actively in the monitoring and management of their diseases, although some of them have difficulties (due to the digital divide) in adjusting to the proposed regime.
- The mobile app prescription process must be simplified and better coordinated with the administrative environments to save clinical professionals time in the prescription process (in order to reduce costs). Although once started it does not present major hurdles, the first steps in the introduction of these tools represents a fixed cost in terms of time devoted to explaining the process to the patient and installing the app on their device, which cannot be assumed by the clinical professional in the consultation time with the patient.
- The users value technology more than the professionals – highlighting which agent takes more responsibility for the intervention.

From the promoter's point of view (the Catalan Ministry of Health), the learning derived from this experience (of great interest at the international level) is that, prior to the deployment of the intervention, it is worthwhile carrying out implementation assessments to evaluate in situ the real impact of the introduction of digital health care tools.

In relation to the interconsultation between the professionals of primary care and hospital care

The study *A Cost-minimization Analysis of Provider-to-provider Telemedicine Compared to Usual care in Catalonia: More Agile and Efficient, Especially for Users* (section 2.3) suggests that interconsultation between professionals has a high potential to resolve clinical consultations (79% of cases), reducing costs for the health system and above all saving users the time and travel expenses involved in hospital visits. According to the case analysed (the Central Catalonia Health Region, a semi-rural area), each visit that is resolved using the interconsultation implies a social saving of €15 of which the majority (85%) benefits the user. In short, these are the lessons learnt:

- The interconsultation between primary care and hospital care is better (compared to usual care) both for the user and the health system. Moreover, the benefit for one party is not to the detriment of the other. The main drivers are the savings in terms of time and commuting costs.
- The digital health tools can have a highly positive impact on the environment in that they serve to reduce unnecessary journeys.
- In urban settings, it is possible that the interconsultation is still preferable to conventional care, although the distance to be covered is not as important as it would be in terms of travel time (as it is much slower to commute in a city than in a rural environment).
- The service's technological requirements are relatively simple, consisting basically of providing access to the professionals involved in the tests performed on the patients, suggesting that some digital health interventions can have a great impact on people's welfare without being excessively expensive or intensive in technology. These consultation schemes are easier to set up thanks to the integration of information systems between primary and hospital environments, as demonstrated by the large number of teledermatology services identified in section 1.3.1.

In relation to the impact of the asynchronous teleconsultation system on face-to-face visits

Several studies in this thesis have explored in different ways the impact on face-to-face visits of the use of eConsultation, the teleconsultation tool used by the public and primary care professionals (described in section 1.3.3.2). As a representative sample, the article *Teleconsultations between Patients and Healthcare Professionals in Primary Care in Catalonia: the Evaluation of Text Classification Algorithms Using Machine Learning* (section 0) includes various of the lessons learnt:

- Methods based on artificial intelligence are technically feasible for evaluating digital health interventions and in the short-term they are probably necessary in order to analyse the volume and types (open text) of data generated.
- Subjective (case-by-case notes by professionals), objective (study of visitor records of visits after having used eConsulta) and artificial intelligence-based approaches give surprisingly similar results, indicating that approximately 80% of teleconsultations are not linked to a subsequent face-to-face visit. Therefore, the eConsultation would achieve the purpose for which it was conceived: to resolve online those enquiries which do not require a face-to-face visit.
- It is observed that most of the virtual consultations were for non-clinical motives, adding value to the face-to-face act and possibly providing the professional with greater job satisfaction.
- In addition, it is observed that approximately 30% of eConsultations would have never taken place in person, suggesting that the reduction in the cost of access to the health professional implies a substantial consultation induction.
- Finally, it is observed that the artificial intelligence-based methods are more robust in approximating binary variables (for example, whether an eConsultation is linked or not to a subsequent face-to-face visit) that in understanding the nature of the clinical case (type of consultation). More resources would be needed (to annotate a bigger message sample) to train an algorithm that would be able to classify the consultations by type in a more reliable way. This potential

development would have applications in the digital healthcare demand management.

3.1.2. With regard to the specific goals

Two specific goals complement the general objective. Based on the experiences outlined in this work, a synthetic answer is given as follows.

Are the digital health interventions promoted by the public health system of Catalonia cost-effective?

On the one hand, the solid architecture of the Catalan public health IT systems provides an enormous opportunity to generate highly cost-effective digital health services. This is suggested by the interconsultation between primary care and hospital care cost-minimization analysis carried out in the Central Catalonia Health Region (section 2.3) and the dozen of experiences identified in the case of teledermatology: the benefits derived from moving the information, rather than people, more than offset the efforts made to integrate the different information systems. Thus, it seems that other low-intensity technological interventions which serve a large population also have good chances of being cost-effective.

On the other hand, it is likely that many interventions which are completely unrelated to the logic of cost-effectiveness are being promoted: as stated in section 1.4 the published evidence from economic assessments, using data from Catalonia, is almost zero, although it may be that the hospital managers have based their decisions on other type of evidence. It should also be borne in mind that the digital health care tools incorporation is a way of testing innovation elements and research in spite of doubts as to their cost-effectiveness: if this is the case, it should be made clear and a commitment made to publish the respective evaluation and not to justify its use on the basis of a hypothetical and unproven cost-effectiveness. It also ought to be noted that if technology is introduced in exchange for sharing the (valuable) data that it generates with the manufacturer, it follows that its value should be included in the analysis calculations as payment in kind.

What is the relationship between the digital health interventions promoted by the Catalan public health system and the use of health resources as a whole?

The two main experiences evaluated in the compendium (the interconsultation between primary care and hospital care and asynchronous teleconsultation between patient and primary care professional) show a high capacity to avoid face-to-face visits (79% and 85% approximately[viii], respectively). This factor, together with the high number of potential beneficiaries (high replicability at zero marginal cost) and the low fixed cost of the technologies, are the driving forces behind the efficiency of the interventions analysed.

The complementarity of the virtual and face-to-face models may imply, among others, a specialization of the reason for the consultation depending on the channel. Therefore, it is important that there exists a strategy which integrates the demand for digital health services (which grows at a very fast pace in the case of teleconsultation in primary care) in the current model.

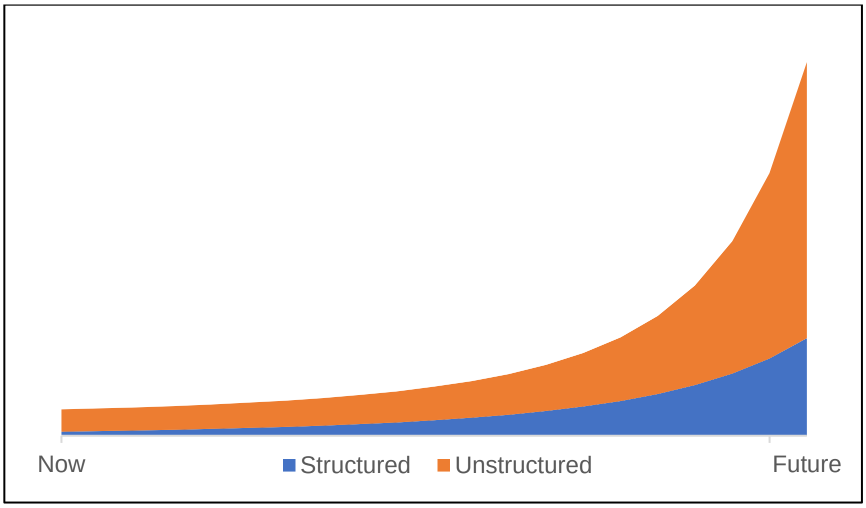
3.2. Digitalization, an opportunity for a new way of evaluating

The way research in the social sciences is conducted is changing. The factors which explain this change are developed below.

3.2.1. Big Data

The use of technology is accompanied by the generation and automatic recording of information. The Catalan public health system is a good example: the administration's information systems (which register the use of resources, referrals and so on), the patient's clinical history (tests results, professionals notes), medical devices (monitoring of variables relating to in-patients), drugs administered and even the emergent incorporation of data from patient's devices which record variables of clinical interest for the general population (steps, hours of sleep) or specific groups (diabetics, asthmatics, people with substance addictions). All these elements make up a set of information with the attributes of Big Data: *variety, velocity, veracity, value* and *volume* (Figure 12).

Figure 12. Expected growth in data availability, by type (simulation)



Moreover, Economics attributes a significant characteristic to information: non-rivalry, by being infinitely copiable, it can be used by an individual without detriment to another. What new possibilities does this new paradigm offer in relation to conventional assessment?

Table 11. Possibilities of the new evaluation. Based in Stephens-Davidowitz (2018)

Before	Now
Small samples. Costs to generate representative samples (randomization).	Analysis of the population at a very low or zero cost (information is automatically recorded). Potential for setting specific focus on subpopulations. Accumulation, temporal series.
Access cost (surveys).	
Potentially unverified, self-declared information (surveys).	Major weight of objective information.
Sophisticated methods to extrapolate evidence to the entire population.	High value placed on descriptive analysis.
Discretionary analysis.	Potential to generate automatic processes, continuous assessment. High replicability.

The data availability allows, for example, for the retrospective analysis of circumstances that can be used as "natural experiments": empirical studies where the study subjects are exposed to specific conditions happening outside the researcher's control[ix]. Moreover, those digital health tools that involve an interaction with the citizenry are possible "A/B Testing" subjects: the random assignment to small variations of a service to generate evidence regarding the impact of a change[x].

Real World Data (Big Data applied in the real world setting, considering its shortcomings) is not exempt from limitations: on one hand, not all sources are whole and reliable; on the other hand, from a strictly technical point of view, the use of this type of data can induce biases in the calculation of the cause-effect relationship. Reality is highly diverse: it is always affected by conditions which are difficult to control in experiments or variations in the type of treatment. For this reason, some scientists argue that, in relation to the use of mass data, randomization is the guarantee that groups of subjects remain comparable in relation to the known and unknown variables, regardless of whether the risk factors have been evaluated (58). These arguments are part of what suggests that Big Data is attributed a predictive power greater than the real one. Therefore, in the coming years, the two approaches must be compared to better understand what the mechanisms that generate the discrepancies in projections are. In the same way, as it has already been pointed out, digitalization also generates opportunities to design randomized procedures at a lower cost within the interventions, reducing (with respect to old-fashioned approaches) its shortages (59,60). In any case, the greater ease in the use of data implies an increase in the advantages of empirical approaches in relation to theoretical ones.

Assessment and interoperability

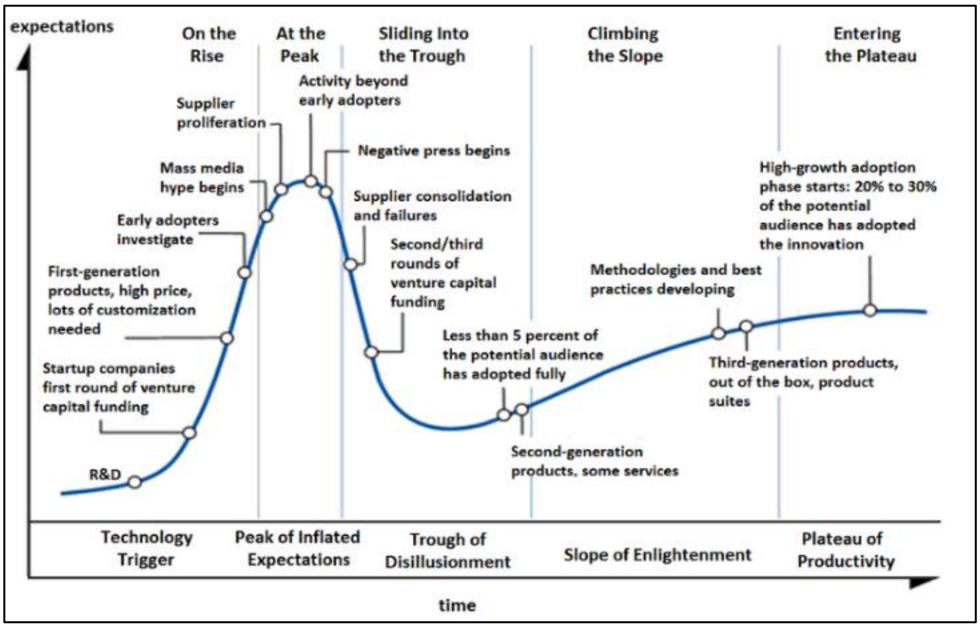
Information has a value proportional to the use that can be derived from it. Therefore, data is neither explanatory nor useful per se*,* instead it is first necessary to analyse it and assess the cost of transforming it so that it can be interpreted. Quality, understood as the proximity between data itself and its potential meaning, is highly heterogeneous according to the context. On one hand, some documents are digitized in unstructured formats which need to be transformed before being analysed (discharge, emergency, radiology or laboratory reports, among others, saved in PDF format), without said transformation capturing the full meaning of the original document. On the other hand, the ability of a given piece of data to maintain its meaning in different environments is called interoperability. Although both public and private initiatives are putting efforts to ensure their data has this attribute, it is still common to find that information systems within the same institution are not interoperable between each other.

Nevertheless, although perfectly structured and interoperable, the explanatory capacity of information is uncertain and difficult to approximate a priori: hence the potential expectations bubble in relation to Big Data and the tools derived from artificial intelligence and the great "*excitement of data scientists to explore the relationships between different sources of information*" (61). A very high number of observations does not imply that they are still susceptible to analysis (see the hypothetical weight of unstructured data in Figure 12) nor, if they are, does it imply sufficient variability to be able to establish clear relationships between variables. This phenomenon of "over-expectations" was made visible by using the Roy Amara argument (named after the futurologist and former president of the Institute for the Future) who suggests that "*we tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run"* (62) (Figure 13). This reality is what makes society, driven by markets and the media, tend to make erroneous and ingenuous forecasts (which are easily forgotten later) regarding the real impact of technology.

The world of data is highly transversal and therefore professionals with backgrounds in economics, engineering or mathematics, among others, are dedicated to Big Data. Out of this fusion of topics dedicated to a single object, the "data scientist" professional profile was born, which is currently in great demand. It would be appropriate that modern evaluation included this type of professional and that it tempered expectations derived from the size of information per se.

A worldwide movement is beginning to call for a broader view of the use of health data based on the premise that data is valuable and despite the privacy challenges it entails it must be more easily made available to science (63). The law, which is increasingly restrictive in favour of citizen's privacy, defends the exercise of their "digital rights" to access the information they generate themselves and to offer it, if they wish to, to third parties so that they can use it as they see fit, in the same way as they can donate blood or an organ. Catalonia has already set up a health research data cooperative (SalusCoop), which calls for the public themselves to coordinate the integration of all data useful for research: public assistance data (which is already the responsibility of the previously mentioned PADRIS), private healthcare data, data coming from wearables or the results of genome sequencing and environmental data, among others. In the context of data abundance and relative lack of means to evaluate it, it is both worthwhile and fair to include the public in the equation: they own the information, they have ideas (ultimately they are the users of the service), they have the right to monitor the public activity from the start and they can provide additional information valuable for the common interests of research. An evaluation and information model including this third-party agent would therefore be appropriate.

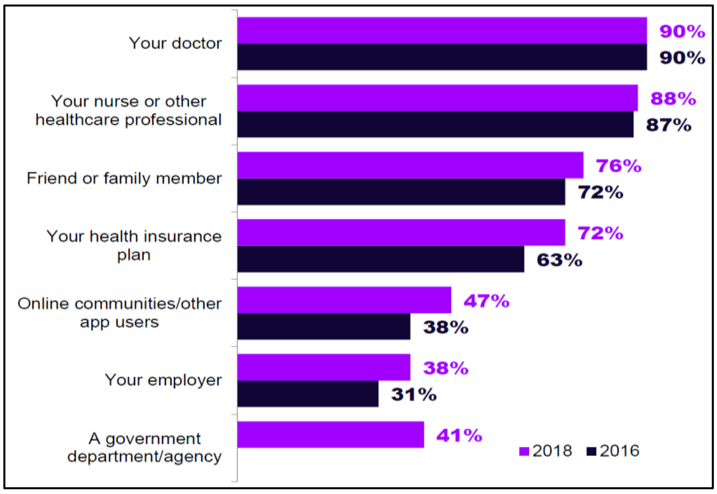
Figure 13. Evolution of the degree of expectation of a technology (the Amara Law or "Hype Cycle")



Source: Gartner Hype Curves

Meanwhile, the administration is also gradually trying to integrate its various information sources. For example, a project promoted by the *Fundació TIC Salut Social* (ICT Social Health Foundation) called *Intersocial*[xi] has the objective of integrating health and social services information. While no scientific evidence exists, it could well be that, from an economic point of view, the potential use of these joint databases more than compensates for the efforts made to make them interoperable. Data originating from the digitalization of clinical and administrative processes is and will progressively be the main raw material in evaluation and must help to inform the decision-making process. Whoever the hub is, and independently of the explanatory power of the artificial intelligence that computes it, this Big Data can be a lever to change the way in which assessment is currently understood.

Figure 14. Would you be willing to share information on your device with the following agents?



3.2.2. Greater processing capacity and new products

On one hand, computer processing power has increased exponentially. Gordon Moore correctly predicted in 1965 that the number of transistors on an integrated circuit would double approximately every two years (64). Now, for an affordable price, one can easily buy a computer able to perform any analysis one can imagine. It is necessary that the evaluation makes the most use of new techniques.

On the other hand, learning is based on observation and testing, and the accumulation of the experiences of previous researchers bring us closer to the answers we seek. In the same way that, since the invention of the printing press, books have been a source of knowledge, today knowledge is accumulated in the form of programs which execute actions instantaneously. In most data science environments these are called “libraries”: small pieces of code which developers have created and reformulated to be effectively and efficiently run on a computer. This type of free programming implies that users have three essential freedoms: to execute the program, to study and change the source code and to distribute identical copies or modified versions.

Moreover, companies related to the digital world cede the use of all or part of their technology for non-commercial or amateur use. An example is the API (Application Program Interface) which Google has made available for its Maps tool in a massive way: in the same manner as an individual is able to calculate, in real time, how long it takes to cover a distance using different routes or types of transport, the same technology can be used to calculate the time it takes a person to access a public resource (as was mentioned in the article in section 2.3). Or how long it takes for all users today, or since records began. Or only those with an age range and a specific health condition, in real time.

The evaluation of public policies can greatly benefit from the use of evaluation tools that take advantage of these possibilities.

3.3. New governance schemes

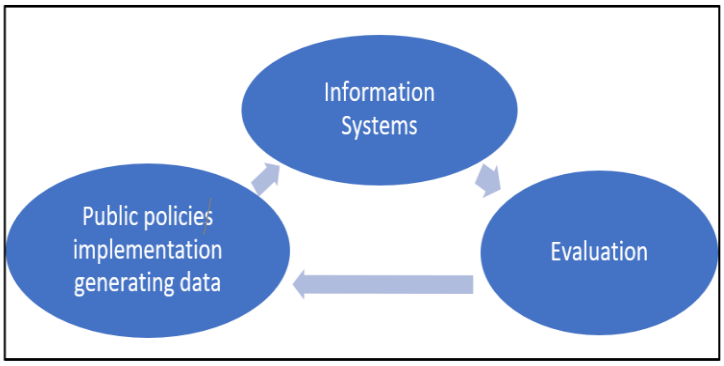
If we want to encourage the evaluation of public policies in Catalonia, making better use of the aforementioned factors, it would be advisable to examine the organizational model and the incentives system that have been used to promote it. The proposed changes are presented below.

Evaluators – data sources tandem

First of all, it would be advisable for the entities which manage the information related to policymaking, among which we find those that provide digital services (we will refer to them as "data sources"), to be more coordinated with the assessment agencies (the "evaluators") and to be more proactive in order to carry out (or let others carry out) evaluations. Bearing in mind that the capacity of the public sector to promote these assessments is limited by the amount of its human resources, a consensus and transparency scheme among the citizens could be created, which would reinforce, in favour of the public interest, the use of data (open or not) and third parties collaborations (research entities and private citizens) under the principle of transparency: data is useful and essential to understanding public action and belong, ultimately, to the population.

In Catalonia, inter-ministerial coordination could be carried out by a tandem of entities which, in a transversal way, are a political reference at a national level (IDESCAT–Ivàlua[xii]) and act as a grouper and coordinator of each of the Ministry's projects, which would also function in pairs. In the case of health, this is already the case: the Ministry of Health' ICTs General Coordination and the Program of Analysis of Data for Research and Innovation in Health (PADRIS) are in contact and form part of the public agency which promotes health assessment (AQuAS). A more "digital" way of thinking and conducting evaluation could translate into shared work objectives between one and the other agencies: to incorporate technologies into the evaluation analysis and the willingness to evaluate at the same time as an intervention is happening and data is collected (Figure 15); that the information systems promote assessment and that assessment goes along with information systems (through indicator display platforms or other continuous assessment systems, with respect to discretionary and non-systematizable assessments promoted until now). To do and to assess at the same time.

Figure 15. Data feed evaluation. Digitalization feeds the information systems



Evaluation and payment models

Secondly, to incorporate incentives appears to be the best alternative (or to eliminate existing disincentives) in systemic practices in order to make evaluation a question which is of interest to all parties. A necessary condition is to impose the "evaluate by default" philosophy into political environments: for example, the relationship models between public contractor and provider could include a system of transparent results, closer to the standards and structure of academic publications so that work can be more easily transferred to this type of environment and can be internationally compared. Payment is conditional on an evaluation being carried out and the results determine future contracts, in accordance with a prior agreement.

In section 1.4.4, we looked at digital health services in the Catalan public sector. In the absence of a prior agreement, the provider's incentive to make public the fact that a service reduces its costs is zero: since the payment can be reduced, it is not interested in publishing a hypothetical evaluation of a technology. Instead, making payment conditional on the realization of an ex-post evaluation (performed with the collaboration of the provider and contractor) the result of which is independent of the payment model between the agents for an agreed number of years, encourages experiences related to innovation to be evaluated in favour of the public interest. Similar schemes ought to be designed and incorporated into other environments.

Evaluating is easier than ever. If the necessary measures were to be adopted, the public sector could base its decision making on much better evidence: in this scenario, the role of decision rules as a complement to political decision making could potentially be enhanced (for example, a cost-effectiveness threshold in health policies, in the style of the British national health service).

3.4. Some final reflections: why evaluate digital health?

Digitalization implies the accumulation of data, the raw material of evaluation: all devices record information and they do so at zero cost. Making use of them is an organizational and managerial challenge, rather than a technical one. It is necessary to evolve from relatively costly studies, out of date and carried out with a reduced number of subjects, to observational studies of population as a whole, integrating as much information as possible from as many sources as possible, incorporating new assessment techniques and the philosophy of open data. Assessment is and has always been essential: it is a sign of a society's level of development. Now, digitalization and technology make it easier. There are fewer excuses not to assess.

Within the public health system, as well as in the personal environment, digital health systems are increasingly used in clinical practice (and are adopted very quickly), despite the relatively weak consensus regarding their efficiency. The lack of published economic evaluations, which would be useful in their favour if they demonstrated savings in resources and/or better clinical results, limits the rigour of this deployment of digitalization. Although in some cases digital health interventions are cost-effective, it is necessary for the public sector to foresee which rules and conditions it will adopt, if any, and how it adapts its economic sustainability model to the growing demand for technology by patients and professionals. Population-based, low-cost interventions and synergies with the public, who already carry a portable device at all times, which is constantly engaged in telemonitoring, surely offer many cost-effective possibilities which ought to be explored. The data age is an excellent opportunity to prove it.

4. Appendices

4.1. Articles

Table 12. Set of articles made during the doctorate

	Article's title	Authorship position	Journal	Impact factor
1	General Practitioners' Perceptions of Whether Teleconsultations Reduce the Number of Face-to-face Visits in the Catalan Public Primary Care System: Retrospective Cross-Sectional Study	1	Journal of Medical Internet Research	4.945
2	Teleconsultation Between Patients and Healthcare Professionals in the Catalan Primary Care Service: Descriptive Analysis through Message Annotation in a Retrospective Cross-Sectional Study	1	Journal of Medical Internet Research	4.945
3	The Prescription of Mobile Apps by Primary Care Teams: A Pilot Project in Catalonia	1	JMIR Mhealth Uhealth	4.301
4	Teleconsultations between Patients and Healthcare Professionals in Primary Care in Catalonia: the Evaluation of Text Classification Algorithms Using Machine Learning	1	International Journal of Environmental Research and Public Health	2.468
5	A Cost-minimization Analysis of a Medical Record-based, Store and Forward and Provider-to-provider Telemedicine Compared to Usual care in Catalonia: More Agile and Efficient, Especially for Users	1	International Journal of Environmental Research and Public Health	2.468
6	COVID-19 and the 5G Conspiracy Theory: Social Network Analysis of Twitter Data	Last	Journal of Medical Internet Research	4.945
7	Primary Care Professionals' Acceptance of Medical Record-Based, Store and Forward Provider-to-Provider Telemedicine in Catalonia: Results of a Web-Based Survey	2	International Journal of Environmental Research and Public Health	2.468
8	Families' Degree of Satisfaction with Pediatric Telehomecare: Interventional Prospective Pilot Study in Catalonia	1	JMIR Pediatrics	No IF
9	An Intergenerational Information and Communications Technology Learning Project to Improve Digital Skills: User Satisfaction Evaluation	1	JMIR Aging	No IF
10	Prescription and Integration of Accredited Mobile Apps in Catalan Health and Social Care: Protocol for the AppSalut Site Design	1	JMIR Research Protocols	No IF
11	The economic impact of the digital transformation of the public health system in Catalonia	1	Nota d'Economia *Not peer reviewed*	No IF
12	Telemedicine in the face of the COVID-19 pandemic	Last	Atención Primaria	1.364
13	Primary Care Doctors Characteristics that Determine their use of Teleconsultations in the Catalan public Health system. Retrospective Descriptive Cross-Sectional Study	2	JMIR Medical Informatics	3.188
14	It's Here to Stay: Benefits and Drawbacks of the eConsulta	2	Atención Primaria Práctica	No IF
15	Impact of a Telemedicine Program on the Reduction in the Emission of Atmospheric Pollutants and Journeys by Road	3	International Journal of Environmental Research and Public Health	2.468
16	Orthopedic Surgeons' Perspectives on the Decision-Making Process for the Use of Bioprinter Cartilage Grafts: Web-Based Survey	3	Interactive Journal of Medical Research	No IF
17	Validation of a Short Questionnaire to Assess Healthcare Professionals' Perceptions of Asynchronous Telemedicine Services: The Catalan Version of the Health Optimum Telemedicine Acceptance Questionnaire	7	International Journal of Environmental Research and Public Health	2.468
18	Sistemas y gestión de la información durante la pandemia de la COVID-19: nada sin los ciudadanos	1	Blog Economía y Salud *Not peer reviewed*	No IF

4.2. Out-of-compendium articles

Below is a list of articles that do not form part of the main compendium of this thesis (except for articles numbered 3–5 in Table 12), but which have also been the subject of research during the same period and which have been referred to throughout this document.

4.2.1. Acceptability and implementation of bioprinted cartilage

Salvador Verges À, Fernández-Luque L, López Seguí F, Yildirim M, Salvador-Mata B, García Cuyàs F. Orthopedic Surgeons' Perspectives on the Decision-Making Process for the Use of Bioprinter Cartilage Grafts: Web-Based Survey Interact J Med Res 2019

Background: Traumatic and degenerative lesions in the cartilage are one of the most difficult and frustrating types of injuries for orthopedic surgeons and patients. Future developments in medical science, regenerative medicine, and materials science may allow the repair of human body parts using 3D bioprinting techniques and serve as a basis for new therapies for tissue and organ regeneration. One future possibility is the treatment of joint cartilage defects with in vivo 3D printing from biological/biocompatible materials to produce a suitable cell attachment and proliferation environment in the damaged site and employ the natural recovery potential of the body. This study focuses on the perspectives of orthopedic surgeons regarding the key factors/determinants and perceived clinical value of a new therapeutic option.

Objective: This study aimed to determine the knowledge and expectations of orthopedic surgeons regarding the clinical use of bioprinted cartilage.

Methods: The survey, conducted anonymously and self-managed, was sent to orthopedic surgeons from the Catalan Society of Orthopedic and Traumatology Surgery. In accordance with the method devised by Eysenbach, the Checklist for Reporting Results of Internet E-Surveys was used to analyse the results. The following factors were taken into consideration: the type and origin of the information received; its relevance; the level of acceptance of new technologies; and how the technology is related to age, years, and place of experience in the field.

Results: Of the 86 orthopedic surgeons included, 36 believed the age of the patient was a restriction, 53 believed the size of the lesion should be between 1 and 2 cm to be considered for this type of technology, and 51 believed that the graft should last more than 5 years. Surgeons over 50 years of age (38/86, 44%) gave more importance to clinical evidence as compared to Surgeons from the other age groups.

Conclusions: The perspective of orthopedic surgeons depends highly on the information they receive and whether it is specialized and consistent, as this will condition their acceptance and implementation of the bioprinted cartilage.

4.2.2. Annotation of teleconsultations in Central Catalonia

López Seguí F, Vidal Alaball J, Sagarra Castro M, García Altés A, García Cuyàs F. General Practitioners' Perceptions of Whether Teleconsultations Reduce the Number of Face-to-face Visits in the Catalan Public Primary Care System: Retrospective Cross-Sectional Study. JMIR 2020

Background: eConsulta is a teleconsultation service involving general practitioners (GPs) and patients. It is part of the information system belonging to Catalonia's primary care service. It has been in operation since the end of 2015 in conjunction with face-to-face consultations with Primary Care Teams (PCT) as one of the services offered in the patient's personal health folder.

Objective: This study aimed to assess the ability of using eConsulta to reduce the number of face-to-face visits to PCTs.

Methods: Using 13 categories proposed by the researchers, 18 GPs from the Central Catalonia Health Region retrospectively classified 2268 cases managed with eConsulta and indicated whether, in their opinion, the teleconsultations reduced the number of face-to-face visits.

Results: There was broad consensus among the GPs that eConsulta has the potential to resolve patient queries for every type of consultation. eConsulta avoided the need for a face-to-face visit in 87.9% of cases. In addition, the GPs reported that the ease of access increased the demand for health care support in 27.7% of cases; otherwise, the patient would not have initiated the queries. Therefore, based on the equation (88% x [1-28%]), eConsulta could replace 63%-88% of conventional appointments. The most frequent uses of the teleconsultation service were for management of test results (35.2%), medical enquiries (16.0%), and the management of repeat prescriptions (12.2%). On average, the teleconsultations consisted of a mean 1.57 messages (SD 0.54 messages); 45.9% (1040/2268) of the teleconsultations consisted of 1 message, and the majority of the remaining teleconsultations consisted of 2-5 interactions. The patient initiated 60.0% (1361/2268) of the teleconsultations.

Conclusions: Based on the GPs' perceptions, eConsulta could replace 63%-88% of conventional appointments. Therefore, asynchronous teleconsultations between practitioners and patients in primary care could avoid interactions that have limited added clinical value.

4.2.3. The environmental impact of telemedicine

Vidal-Alaball, J., Franch-Parella, J., Lopez Seguí, F., Garcia Cuyàs, F., & Mendioroz Peña, J. Impact of a Telemedicine Program on the Reduction in the Emission of Atmospheric Pollutants and Journeys by Road. International Journal of Environmental Research and Public Health 2019

This retrospective study evaluates the effect of a telemedicine program developed in the central Catalan region in lowering the environmental footprint by reducing the emission of atmospheric pollutants, thanks to a reduction in the number of hospital visits involving journeys by road. Between January 2018 and June 2019, a total of 12,322 referrals were made to telemedicine services in the primary care centres, avoiding a total of 9034 face-to-face visits. In total, the distance saved was 192,682 km, with a total travel time saving of 3779 h and a total fuel reduction of 11,754 L with an associated cost of €15,664. This represents an average reduction of 3248.3 g of carbon dioxide, 4.05 g of carbon monoxide, 4.86 g of nitric oxide and 3.2 g of sulphur dioxide. This study confirms that telemedicine reduces the environmental impact of atmospheric pollutants emitted by vehicles by reducing the number of journeys made for face-to-face visits, and thus contributing to environmental sustainability.

4.2.4. Economic impact of digital transformation

López Seguí F, Martí Aguasca T. The economic impact of the digital transformation of the public health system in Catalonia. Nota d'Economia. Monographic "The digital revolution in Catalonia". Pages 181-192. 2019

This article describes the state of implementation of information and communication technologies in the public health services delivery in Catalonia and outlines the main implications to the economic sustainability model of the health system. Robotics, Big Data, artificial intelligence, mobile technologies, telemedicine, virtual, augmented and mixed reality, wearables, blockchain or 3D bioprinting are some of the technologies included in the so-called "digital health". As in the personal context and each technology at their own pace, they are increasingly used in clinical practice despite the relatively weak scientific consensus supporting them, with some exceptions, compared to other interventions studied by health economics. The lack of published economic evaluations, which would be useful in the case of saving resources and/or better clinical results, limits the deployment's rigorousness of this digitalization. In the meantime, the public sector must foresee under what rules and conditions it will adopt them and how it adapts its model of economic sustainability to the growing demand for technification of patients and professionals. The reduction in the cost of devices or the synergies with citizens, who already have a telemonitoring device in their pockets (cell phones), unfold certainly many cost-effective possibilities.

4.2.5. Benefits and disadvantages of teleconsultation in Catalonia

Vidal-Alaball J, López Seguí F. It's here to stay: benefits and drawbacks of eConsultation. Atención Primaria Práctica. 2020

Begun at the end of 2015, eConsulta is an asynchronous teleconsultation service which forms part of the primary care IT systems belonging to the public health system of Catalonia. It was introduced gradually: since 2017 it has become a complement to face-to-face consultations and is currently available to 93% of primary care centres. Although initially it was a tool solely intended for general practitioners, it can now also be used by pediatricians and nurses. From the general public's point of view, eConsultation is one of the services offered in their personal health folder, a digital space which allows individuals to access their health information, ask questions and carry out certain administrative procedures. Once a user has accessed the space, which employs secure authentication measures (with its corresponding difficulties for a typical user), the eConsultation interface allows them to choose which professional to direct their enquiry to and to attach files. It also maintains a record of previous interactions. At present, less than 1% of primary care consultations in Catalonia are eConsultations. However, the possible and likely increase in this type of activity, make it worthwhile reflecting on the pros and cons of its use in order to guide its development in the future.

A recent study found that the main reasons for a primary care consultation by means of an eConsultation is the management of diagnostic tests (33%), clinical reasons (17%) and the management of medication (12%), and that there is a broad consensus among professionals that eConsultation has a very high capacity to resolve patient queries (avoiding a face-to-face visit in 88% of cases) for all types of consultation. The tool thus meets the objective of resolving queries without the need for a face-to-face visit, saving the time difference between a face-to-face and a virtual visit (and it does so more efficiently than telephone visits, where the doctor and patient need to agree on a time) and reducing the time and environmental impact of patient journeys. It is also able to manage separately cases of low clinical added value (with its corresponding potential in the specialization of case management), while allowing professionals to better self-manage their agenda, thus increasing their job satisfaction. Among its other possible benefits, other factors should also be considered: the offer of a new relational model with health professionals, more practical for the user and one which favours their empowerment; the possibility of promoting telework by professionals, improving family reconciliation; and the potential for using evaluation tools based on artificial intelligence (such as image analysis and text classification using natural language processing techniques).

Nonetheless, the service is not free from potential inconveniences. Firstly, it can induce demand for trivial reasons, which may be as high as 30% of eConsultations. These may increase as access becomes easier (via a mobile app, for example). Secondly, it can lead to inequalities in the use of the service, with differences in access for specific groups of patients according to their resources or digital skills (the elderly, a highly recurrent group in primary care). Such inequalities could also exist among professionals who are less familiar with technology. According to another recent study, this is not related to the age of the professional as it has been observed that the average age of medical professionals who use eConsultation is approximately 45.

Regardless of whether the benefits outweigh the drawbacks, the growing use of the tool (also in private healthcare, which are traditionally more technology-driven environments) suggests that eConsultation is here to stay. The good news is that the following articles, some of which have been quoted here, can be used by healthcare decision makers to study their characteristics and impact in order that they can take the right decisions.

4.2.6. Design of the telemonitoring system using mobile applications

López Seguí F, Pratdepàdua Bufill C, Rius Soler A, de San Pedro M, López Truño B, Aguiló Laine A, Martínez Roldán J, García Cuyàs F. Prescription and Integration of Accredited Mobile Apps in Catalan Health and Social Care: Protocol for the AppSalut Site Design. JMIR Res Protoc 2018

Background: The use of new mobile technologies in the health and social welfare sectors is already a reality. The *Fundació TIC Salut Social* (ICT Social Health Foundation), in accordance with the technology strategy of the Catalan government's Ministry of Health and its Ministry of Labour, Social Affairs and Families, is leading an initiative to create a public library of apps for its AppSalut Site.

Objective: The objective of this paper is to present an account of the design of the project, with a global perspective, applied to the Catalan ecosystem, which can be divided into 3 areas: the framework governing the recommendation and prescription of apps, the subset of interoperability for mobile environments, and the data storage infrastructure.

Methods: The security and credibility of the apps included in the catalogue is ensured by submitting them to an accreditation process in the public domain that provides users with the guarantee that they are fit for purpose and trustworthy for the management and care of their health, while providing health care professionals with the possibility of recommending the apps in the doctor's surgery, as well as adding the information generated by the users' mobile devices to the information systems of the various organizations concerned.

Results: An examination of the abovementioned areas suggests possibilities for improvements in the future. The experience obtained from the development of this element has shown the heterogeneity of the vocabularies used, as expected, due to the lack of awareness on the part of the developers regarding the need to standardize the information generated by the app, requiring the foundation to take on the role of consultant.

Conclusions: The project has evolved in keeping with changes in the technological and social paradigm and responds very satisfactorily to the needs posed to it. It can be seen as a landmark experience in mobile strategies in the fields of health and welfare of any public health system. The experience has shown itself to be feasible in organizational terms, necessary in any attempt to integrate mobile technologies into public health practice, and a global pioneer in the field.

4.2.7. The profile of the professionals who use the teleconsultation in Catalonia

Solans Fernández O, Lopez Seguí F, Vidal-Alaball J, Bonet Simo JM, Hernandez Vian O, Roig Cabo P, Carrasco Hernandez M, Olmos Dominguez C, Alzaga Reig X, Díaz Rodríguez Y, Medina Peralta M, Hermosilla E, Martínez León N, Gimferrer N, Abizanda González M, García Cuyàs F, Pérez Sust P. Primary Care Doctor Characteristics That Determine the Use of Teleconsultations in the Catalan Public Health System: Retrospective Descriptive Cross-Sectional Study. JMIR Med Inform 2020;8(1):e16484

Background: eConsulta is a teleconsultation service involving doctors and patients and is part of Catalonia's public health information technology system. The service has been in operation since the end of 2015 as an adjunct to face-to-face consultations. A key factor in understanding the barriers and facilitators to the acceptance of the tool is understanding the sociodemographic characteristics of general practitioners who determine its use.

Objective: This study aimed to analyse the sociodemographic factors that affect the likelihood of doctors using eConsulta.

Methods: A retrospective cross-sectional analysis of administrative data was used to perform a multivariate logistic regression analysis on the use of eConsulta in relation to sociodemographic variables.

Results: The model shows that the doctors who use eConsulta are 45-54 years of age, score higher than the 80th percentile on the quality of care index, have a high degree of accessibility, are involved in teaching, and work on a health team in a high socioeconomic urban setting.

Conclusions: The results suggest that certain sociodemographic characteristics associated with general practitioners determine whether they use eConsulta. These results must be taken into account if its deployment is to be encouraged in the context of a public health system.

4.2.8. Impact on the satisfaction of the families of pediatric telemonitoring

López Seguí F, Batlle Boada A, García García JJ, López Ulldemolins A, Achotegui del Arco A, Adroher Mas C, García Cuyàs F. Families' degree of satisfaction with pediatric telehomecare: a pilot study in Catalonia. JMIR Pediatrics (2020).

Background: Pediatric home hospitalization improves the quality of life of children and their families, involving them in their children's care, while favouring the work-life balance of the family. In this context, technology guarantees accessibility to assistance, which provides security to users. From the perspective of the health care system, this could lower the demand for hospital services and reduce hospitalization costs.

Objective: This study aimed to assess families' degree of satisfaction and acceptability of pediatric telehomecare and explore the clinical characteristics of children benefiting from the program.

Methods: A total of 95 children and their families participated in the home-hospitalization pilot program operated by Sant Joan de Déu Hospital in Barcelona, Spain. Families were visited once a day and patients were monitored using a kit consisting of a scale, a thermometer, a pulse oximeter, and a blood pressure monitor. Data on parental experience, satisfaction, safety, and preference for care was collected by means of a questionnaire. Data about the children's characteristics were collected from medical records. Descriptive and comparative statistics were used to analyse the data.

Results: A total of 65 survey respondents expressed very high levels of satisfaction. Families reported their experiences as being very positive, preferring home hospitalization in 94% (61/65) of cases, and gave high scores regarding the use of telemonitoring devices. The program did not record any readmissions after 72 hours and reported a very low number of adverse incidents. The user profile was very heterogeneous, highlighting a large number of respiratory patients and patients with infections that required endovenous antibiotic therapy.

Conclusions: Pediatric home hospitalization through telemonitoring is a feasible and desirable alternative to traditional hospitalization, both from the perspective of families and the hospital. The results of this analysis showed a very high degree of satisfaction with the care received and that the home-based telemonitoring system resulted in few adverse incidents.

4.2.9. Validation of a telemedicine acceptability questionnaire

Vidal-Alaball, J.; Flores Mateo, G.; Garcia Domingo, J.L.; Marín Gomez, X.; Sauch Valmaña, G.; Ruiz-Comellas, A.; López Seguí, F.; García Cuyàs, F. Validation of a Short Questionnaire to Assess Healthcare Professionals' Perceptions of Asynchronous Telemedicine Services: The Catalan Version of the Health Optimum Telemedicine Acceptance Questionnaire. Int. J. Environ. Res. Public Health 2020, 17, 2202.

Telemedicine is both effective and able to provide efficient care at a lower cost. It also enjoys a high degree of acceptance among users. The Technology Acceptance Model proposed is based on the two main concepts of ease of use and perceived usefulness and is comprised of three dimensions: the individual context, the technological context and the implementation or organizational context. At present, no short, validated questionnaire exists in Catalonia to evaluate the acceptance of telemedicine services amongst healthcare professionals using a technology acceptance model. This article aims to statistically validate the Catalan version of the EU project Health Optimum telemedicine acceptance questionnaire. The study included the following phases: adaptation and translation of the questionnaire into Catalan and psychometric validation with construct (exploratory factor analysis), consistency (Cronbach's alpha) and stability (test–retest) analysis. After deleting incomplete responses, calculations were made using 33 participants. The internal consistency measured with the Cronbach's alpha coefficient was good with an alpha coefficient of 0.84 (95%, CI: 0.79–0.84). The intraclass correlation coefficient was 0.93 (95% CI: 0.852–0.964). The Kaiser–Meyer–Olkin test of sampling showed to be adequate (KMO = 0.818) and the Bartlett test of sphericity was significant (Chi-square 424.188; gl = 28; $p < 0.001$). The questionnaire had two dimensions which accounted for 61.2% of the total variance: quality and technical difficulties relating to telemedicine. The findings of this study suggest that the validated questionnaire has robust statistical features that make it a good predictive model of healthcare professional's satisfaction with telemedicine programs.

4.2.10. Annotation of teleconsultations for the characterization of the consultation motive: extension of the study carried out in the Central Catalonia Health Region

López Seguí F, Walsh S, Solans O, Adroher Mas C, Ferraro G, García-Altés A, García Cuyàs F, Salvador Carulla L, Vidal-Alaball J. Teleconsultation Between Patients and Healthcare Professionals in the Catalan Primary Care Service: Descriptive Analysis through Message Annotation in a Retrospective Cross-Sectional Study. JMIR.

Background: Over the last decade telemedicine services have been introduced in the public healthcare systems of industrialized countries. In Catalonia, the use of eConsulta, an asynchronous teleconsultation between primary care professionals and citizens in the public healthcare system has already reached 400,000 cases and is growing at a monthly rate of 7%. Despite its widespread usage, there is little qualitative evidence describing how this tool is used.

Objective: To annotate a random sample of these teleconsultations and to evaluate the level of agreement between healthcare professionals with respect to the annotation.

Methods: 20 GPs retrospectively annotated a random sample of 5,382 cases managed with eConsulta according to 3 variables: the type of interaction according to 6 author-proposed categories, whether the practitioners believed a face-to-face visit was avoided, and whether they believed the patient would have requested a face-to-face visit had eConsulta not been available. 1,217 cases were classified three times, by three different professionals, to assess the degree of consensus among them.

Results: In response to the question "Has the online consultation avoided a face-to-face visit?", GPs answered Yes for 79,6% (4,284/5,382) of the teleconsultations, while to the question "In the absence of a service like eConsulta, would the patient have made a face-to-face visit?" GPs answered Yes 65% (3,496/5,382) of the time. The most frequent uses were for management of test results (26.8%, 1,433/5,354), the management of repeat prescriptions (24.3%, 1,301/5,354) and medical enquiries (14.2%, 762/5,354). The degree of agreement among professionals as to the annotations is mixed, with the highest consensus being for the variable "Has the online consultation avoided a face-to-face visit?" (3/3 professionals agreed 68% of the time (827/1,217), and the lowest for the type of use of the teleconsultation (3/3 professionals agreed 57.6% of the time, 701/1,217).

Conclusions: This study shows eConsulta's ability to reduce the number of face-to-face visit stands at between 55% (79% x 65%) and 79% of cases. In comparison to previous research, these results are a bit more pessimistic while figures are still high and in line with administrative data' proxies, which show 84% of teleconsultations do not register an in-person appointment in the following 3 months. With respect to the type of consultation performed, results are similar to previous literature, thus giving robust support to the eConsulta's usage. The mixed degree of consensus among professionals implies that results derived from AI applications such as message classification algorithms should be understood in light of these shortcomings.

4.2.11. Telemedicine in the face of the pandemic

Vidal-Alaball, J; Acosta-Rojas, R; Pastor, N; Sanchez, U; Morrison, D; Narejos, S; Pérez Llano, J; Salvador, A; López Seguí, F. Telemedicine in the face of the COVID-19 pandemic. Atención Primaria 2020.

The novel coronavirus SARS-CoV-2 is a positive single-stranded RNA virus that can be immediately translated and integrated into the host cell with its own RNA messenger, facilitating replication inside the cell and infectivity. The rapid progression of the disease presents a real challenge for the whole world. As the usual capacity for citizen care is exceeded, health professionals and governments struggle. One of the most important strategies to reduce and mitigate the advance of the epidemic are social distance measures; this is where telemedicine can help, and provide support to the healthcare systems, especially in the areas of public health, prevention and clinical practices, just as it is doing in others sectors. Telemedicine connects the convenience, low cost, and ready accessibility of health-related information and communication using the Internet and associated technologies. Telemedicine during the coronavirus epidemic has been the doctors' first line of defense to slow the spread of the coronavirus, keeping social distancing and providing services by phone or videoconferencing for mild to focus personal care and limited supplies to the most urgent cases.

4.2.12. Analysing the conspiracy theory linking 5G to COVID-19 through social network analysis

Ahmed W, Vidal-Alaball J, Downing J, Lopez Seguí F. Dangerous Messages or Satire? Analysing the Conspiracy Theory Linking 5G to COVID-19 through Social Network Analysis. JMIR Preprints (2020)

Background: Since the beginning of December 2019 COVID-19 has spread rapidly around the world which has led to increased discussions across online platforms. These conversations have also included various conspiracies shared by social media users. Amongst them a popular theory has linked 5G to the spread of COVID-19 leading to misinformation and the burning of 5G towers in the United Kingdom. The understanding of the drivers of fake news and quick policies oriented to isolate and rebate misinformation are key to combating it.

Objective: To develop an understanding of the drivers of the 5G COVID-19 conspiracy theory and strategies to deal with such misinformation.

Methods: This paper performs a Social Network Analysis and Content Analysis of Twitter data from a 7-day period in which the #5GCoronavirus hashtag was trending on Twitter. Influential users are analysed through social network graph clusters. The size of the nodes is ranked by their betweenness centrality score and the graph's vertices are grouped by cluster using the Clauset-Newman-Moore algorithm. Topics and Web sources utilized by users are examined.

Results: Social Network Analysis identified that the two largest network structures consisted of an isolates group and a broadcast group. The analysis also reveals that there was a lack of authority figure who was actively combating such misinformation. Content analysis reveals that only 35% of individual tweets contained views that 5G and COVID-19 were linked whereas 32% denounced the conspiracy theory and 33% were general tweets not expressing any personal views or opinions. Thus, 65% of tweets derived from non-conspiracy theory supporters which suggests that although the topic attracted high volume only a handful of users genuinely believed the conspiracy. This paper also shows that fake news websites were the most popular Web-source shared by users although YouTube videos were also shared. The study also identified an account whose sole aim was to spread the conspiracy theory on Twitter.

Conclusions: The combination of quick targeted interventions oriented to delegitimize the sources of fake information are key to reducing their impact. Those users voicing their views against the conspiracy theory, link-baiting, or sharing humorous tweets inadvertently raised the profile of the topic, suggesting that policymakers should insist in the efforts of isolating opinions which are based on fake news. Many social media platforms provide users with the ability to report inappropriate content. This study is the first to analyse the 5G conspiracy theory in the context of COVID-19 on Twitter offering practical guidance to health authorities in how, in the context of a pandemic, rumours may be combated in the future.

4.2.13. Reducing the digital divide through intergenerational learning

López Seguí F, de San Pedro M, Aumatell Verges E, Simó Algado S, Garcia Cuyàs F. An Intergenerational Information and Communications Technology Learning Project to Improve Digital Skills: User Satisfaction Evaluation. JMIR Aging 2019

Background: "Digital Partners" is an intergenerational information and communications technology learning project carried out in the municipalities of Vic and Centelles (Catalonia) from April to May 2018. Within the framework of the introduction of community service as a subject in secondary education, the Centre for Health and Social Studies (University of Vic) created a training space with 38 intergenerational partners (aged 14-15 years and >65 years), with the aim of improving the senior users' digital skills in terms of use of smartphones and tablets, thus helping reduce the digital divide in the territory.

Objective: The aim of this paper is to evaluate the satisfaction of both junior and senior participants toward the intervention and to explore its main drivers.

Methods: Participants who volunteered to participate in the study were interviewed. Quantitative and qualitative data gathered in paper-based ad hoc surveys were used to assess participants' satisfaction.

Results: The experience shows a broad satisfaction of both junior and senior users. The project's strengths include the format of working in couples; randomly pairing individuals by operating system; the ability to practice with the device itself; individuals' free choice to decide what they wish to learn, develop, or practice; and the availability of voluntary practice material that facilitates communication and learning. With regard to aspects that could be improved, there is a need to review the timetabling flexibility of meetings to avoid hurrying the elderly and to extend the project's duration, if necessary.

Conclusions: This activity can serve to create mutual learning through the use of mobile devices and generate security and motivation on the part of the seniors, thus reducing the digital divide and improving social inclusion.

4.2.14. Information systems during COVID-19: nothing without citizens

López Seguí, F; García-Altés, A. Sistemas y gestión de la información durante la pandemia de la COVID-19: nada sin los ciudadanos. Blog Asociación de Economía de la Salud. Especial "Economía de la salud (y más) de la COVID-19". 2020

The amount of data is growing, say the most reputable futurologists, at an exponential rate. The "oil of the 21st century" (according to Angela Merkel) is a non-rival good (the use by one does not prevent another from using it) and exclusive (it is possible to discriminate between who will enjoy it and who will not), which is embedded between the interesting club goods. When the term Big Data was socialized a decade ago, futurologists (perhaps they themselves) said that "in the distant 2020" the world would change (among other unfortunate forecasts, such as that "robotics will replace a very important part of the working class ": it is true that there are many more Roomba robots, but otherwise we continue as before). Perhaps the change has occurred in private interest settings, where the revolution is intentionally silent, but so far little of that expected value has reached the public health environment. Ditto for blockchain, artificial intelligence, virtual reality and others, with very celebrated exceptions (medical image analysis algorithms).

The COVID-19 pandemic has been a "surprise selectivity" for health systems. The examination of the Massive Use of Data for a More Efficient Management of Pandemics has been demanding: suddenly, we have been in need of real-time, population-wide information with a high level of detail. Perhaps it has caught us with more theory than practice. Part of the agenda, which we review below using the famous five "Vs", is applicable beyond the pandemic situation.

4.2.15. Professionals' acceptance of telemedicine in Central Catalonia

Vidal-Alaball, J.; López Seguí, F.; Garcia Domingo, J.L.; Flores Mateo, G.; Sauch Valmaña, G.; Ruiz-Comellas, A.; Marín-Gomez, F.X.; García Cuyàs, F. Primary Care Professionals' Acceptance of Medical Record-Based, Store and Forward Provider-to-Provider Telemedicine in Catalonia: Results of a Web-Based Survey. Int. J. Environ. Res. Public Health 2020, 17, 4092.

While telemedicine services enjoy a high acceptance among the public, evidence regarding clinician's acceptance, a key factor for sustainable telemedicine services, is mixed. However, telemedicine is generally better accepted by both patients and professionals who live in rural areas, as it can save them significant time. The objective of this study is to assess the acceptance of medical record-based, store and forward provider-to-provider telemedicine among primary care professionals and to describe the factors which may determine their future use. This is an observational cross-sectional study using the Catalan version of the Health Optimum questionnaire; a technology acceptance model-based validated survey comprised of eight short questions. The online, voluntary response poll was sent to all 661 primary care professionals in 17 primary care teams that had potentially used the telemedicine services of the main primary care provider in Catalonia, in the Central Catalan Region. The majority of respondents rated the quality of telemedicine consultations as “Excellent” or “Good” (83%). However, nearly 60% stated that they sometimes had technical, organizational or other difficulties, which might affect the quality of care delivered. These negatively predicted their declared future use (p = 0.001). The quality of telemedicine services is perceived as good overall for all the parameters studied, especially among nurses. It is important that policymakers examine and provide solutions for the technical and organizational difficulties detected (e.g. by providing training), in order to ensure the use of these services in the future.

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6. Footnotes

[i] Etymologically, “data” (from the word *datum) means “*given thing”: a fact, a condition which is assumed to be certain.
[ii] IDESCAT 2017.
[iii] http://aquas.gencat.cat/ca/ambits/analitica-dades/padris/
[iv] As if it were a business case study or a budget analysis.
[v] Cost-efficacy analysis is a method of comparing programs and projects which is equivalent to CEA but in ideal or non-environmental conditions (“laboratory conditions”) which is only used prior to the introduction of a new program.
[vi] Being a “search for reviews”, it also involves the inclusion of earlier articles. The [“economic” / “cost-utility” / “cost effectiveness” + “telemedicine” / “telehealth” / “mHealth” + “review”] parameters were used in the title and in exploring related searches (including terms cost-effectiveness, cost-utility, cost analysis, economic evaluation). The search was performed on January 12, 2019.
[vii] Some have been published by initiative of the Fundació TIC Salut Social (Ministry of Health) prioritizing the need to highlight innovation projects within the public health system of Catalonia.
[viii] 84% according to data relating the use of eConsultation to a subsequent visit (eSalut Office, 2020); 88% according to professionals.
[ix] Imagine that the northern part of a territory is affected by an absolute lack of fuel so that users cannot travel by car or public transport: those who live in towns far from hospitals cannot access them. This circumstance would be useful to explore how the restriction in access to hospital care heterogeneously affects the health status of the population: the southern part of the territory, not affected by the effect of this shortage, would serve as a counterfactual to generate an experience of “differences in differences” that take into account the differential health status between those who live in a town and those who live in a city.
[x] An example: we wish to quantify the potential amount of teleconsultations which could be directed to nurses (currently less than half) instead of general practitioners. In the eConsultation interface, the patient can select whether to send the message to one or the other. The “A/B” experiment would consist of changing the shape or place of the options (nurses by default, for example) to highlight one option above the other. Some users could change their use: the volume that these represent over the total would suggest how many consultations that users currently make to medical professionals could be transferred to nurses.
[xi]https://ticsalutsocial.cat/projectes/oficina-interoperabilitat/interoperabilitat-semantica/projecte-intersocial
[xii] On the occasion of the UN’s World Statistics Day on October 20, 2015, the Statistical Institute of Catalonia (IDESCAT) published its “Data Manifesto” with the aim of “raising awareness among governments and society that the correct use of data can provide many different opportunities in different areas of social and economic life for the 21st century”. IDESCAT, as the entity which presides over the Catalan Institute of Public Policy Assessment (Ivàlua), considers assessment to be one of the major priorities in the use of data. See: https://www.idescat.cat/metodes/manifestdades/en