A Qualitative Evaluation of IoT-driven eHealth: Knowledge Management, Business Models and Opportunities, Deployment and Evolution

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Abstract

eHealth has a major potential, and its adoption may be considered necessary to achieve increased ambulant and remote medical care, increased quality, reduced personnel needs, and reduced costs potential in healthcare. In this paper the authors try to give a reasonable, qualitative evaluation of IoT-driven eHealth from theoretical and practical viewpoints. They look at associated knowledge management issues and contributions of IoT to eHealth, along with requirements, benefits, limitations and entry barriers. Important attention is given to security and privacy issues. Finally, the conditions for business plans and accompanying value chains are realistically analyzed. The resulting implementation issues and required commitments are also discussed based on a case study analysis. The authors confirm that IoT-driven eHealth can happen and will happen; however, much more needs to be addressed to bring it back in sync with medical and general technological developments in an industrial state-of-the-art perspective and to get recognized and get timely the benefits.

1. Introduction

There are high expectations for eHealth as a major tool to achieve the following improvements in healthcare: a further shift from clinical to ambulant treatment; reductions in the per user/patient workload of medical and care staff; improvements in the quality of medical and care services for users/patients; and last but not least, significant reductions in the medical treatment and care cost per user/patient. The attention, and hype, around the Internet of Things (IoT) [14, 15], and, in particular, IoT-driven eHealth [6], has further increased the visibility and expectation of eHealth. In this paper the authors make an effort to give a reasonable, qualitative evaluation of what can be expected of IoT in eHealth [11] and IoT-driven eHealth itself [6]. They look at the possible contributions of IoT to eHealth, the requirements that need to be met, the benefits and limitations of eHealth, and the entry barriers [5, 16, 18]. Important attention is given to security and privacy, representing an important set of issues [3, 9, 12, 20]. However, the authors conclude that these are not the first issues to be addressed: first there needs to be a joint understanding between the users/patients and healthcare providers that there are benefits for both the users/patients and healthcare providers in applying eHealth [5, 12, 13, 18]. The conditions for business plans and accompanying value chains are realistically analyzed, and the resulting implementation issues and commitments are discussed [5, 14, 15, 18]. As a result, the paper contributes to the literature by reviewing, innovatively, business models, strategic implications and opportunities for IoT-driven eHealth, as well as its deployment and evolution.

This paper is comprised of six sections and is organized as follows. Section two provides a theoretical view on the IoT-driven eHealth in the context of Knowledge Management (KM). Section three contains a case study on improving patient discharge planning process through knowledge management by using IoT and Big Data in the UK National Health Service [11, 17], to illustrate a strong connection between KM and IoT-driven eHealth. This section focuses on contributions of IoT to eHealth and analyzes requirements, limitations and entry barriers for IoT-driven eHealth, as well as security and privacy issues, having established that these issues are not the first topics to be addressed, but the benefits of applying eHealth instead. Section four examines conditions for business plans and associated value chains and reflects on implementation issues and commitments. Section five contains conclusions. Section six lists references.

2. Theoretical view on IoT-driven eHealth

Views on eHealth. Everybody talks about eHealth these days, but few people have come up with a clear definition of this term. The term was apparently first used by industry leaders and marketing people rather than academics, and they used this term in line with other "e"-words such as eCommerce, eBusiness, eTrade and so on.

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So, how can the authors define eHealth in the academic environment? It seems quite clear that eHealth encompasses more than a technological development. The authors can define the term and the notion as follows: eHealth is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the communication technology, i.e., the Internet, and related technologies [13]. In a broader sense, the term 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. As such, the “e” in eHealth does not only stand for “electronic”, but implies a number of other “e’s,”, which together, perhaps, best describe what eHealth is all about, or what it should be [7].

Views on IoT. IoT is a system that relies on autonomous communication of groups of physical objects. IoT, in the context of the digital revolution, is an emerging global communications/Internet-based information architecture facilitating the exchange of knowledge, services and goods [5]. The authors expect that main domains of IoT will be transportation and logistics; healthcare; smart environment (home, office and plant, integrated in the environment); and personal and social area [11, 13, 14, 15, 16].

In Table 1 the authors consider realms of ubiquitous society. This entity is called the multiversity. Table 1 suggests that leaders, managers and planners must understand the fundamental nature of three elements of reality: time, space and matter. The new service designs, architectures and business models are needed in the multiverse, not only in the universe.

Table 1. Realms in the ubiquitous society and in the multiverse

Variables			Realm
1. Time	Space	Matter	Reality
2. Time	Space	No-matter	Augmented reality
3. Time	No-space	Matter	Physical reality
4. Time	No-space	No-matter	Mirrored reality
5. No-time	Space	Matter	Warped reality
6. No–time	Space	No-matter	Alternative Reality
7. No-time	No-space	Matter	Augmented Virtuality
8. No-time	No-space	No-matter	Virtuality

What is obvious is that managers must work in order to manage these critical eight realms of the ubiquitous society [18, 19]. The applications of IoT are numerous, basically meaning smart things and smart systems such as smart homes, smart cities, smart industrial automation and smart services. IoT systems provide better productivity, efficiency and better quality to numerous service providers and industries. IoT is based on social, cultural and economic trust and associated trust management skills, which broadly speaking mean developed security services and antifragility operations. Critical issues of the IoT security field are trusted platforms, low-complexity, encryption, access control, secure data, provenance, data confidentiality, authentication, identity management, and privacy-respecting security technologies. Security of IoT requires data confidentiality, privacy and trust. These security issues are managed by distributed intelligence, distributed systems, smart computing and communication identification systems [14, 15].

Finally, key systems of global economy are markets, networks and crowds. IoT can be found among these key systems of global economy. Probably, there is a lot of potential for smartness between these key systems. Data, information and knowledge about communication and interaction of these systems are vital issues for the future of management [14, 15, 16].

Especially the Internet of Intelligent Things (IoIT), defined by experts as smart Machine-to-Machine (M2M) communication, provides much potential for crowdsourcing of markets and networks. IoIT provides also much potential for smart networking (between markets and networks and between various networks) [5]. The authors expect that one obvious consequence of IoIT will be a broader scope of deliberate democracy. Additionally, the legal framework of IoT/IoIT is still considered rather vague, or absent in a certain sense. Such issues like standardization, service design architecture, service design models, data privacy and data security create management and governance problems, which are not, or at least not completely solved inside current service architectures [14, 15]. IoT has also become subject to power politics because of risks of cyber war, cyber terror and cyber criminality. Last but not least, the authors can see that IoT will be central for the collection of raw Big Data, captured from the environment, human beings and robots and AI applications [13, 14, 15, 16].

Views on IoT and Big Data in the context of knowledge management. The Data-Information-Knowledge-Wisdom (DIKW) model is an often used method, with roots in knowledge management [2], to explain the ways to move from data to information, knowledge and wisdom with a component of actions and decisions. Simply put, it is a model to look at various ways of extracting insights and value from all sorts of data, big, small, smart, fast and slow. It is often depicted as a hierarchical model in the shape of a pyramid and also known as the data-information-knowledge-wisdom hierarchy, among others [1, 4, 19]. Ackoff (1989) had originally defined the traditional DIKW model as provided below [1].

Data is the result of a relatively accurate observation, and it may or may not be inspired by a problem to be solved. Data comprises objective facts, signs and numbers, and it does not need relationships with other elements to exist, but if to take each data individually, it does not communicate anything and does not contain any meaning. Data is something perceived by the senses (or sensors) but it has no intrinsic value until it is put in a context. Data becomes information only when it is placed in context, through contextualization (in fact), categorization, processing, correction and synthesis.

Information, deduced from the data, includes all data, giving them meaning and gaining added value compared to the data. Information is the choice to put some data in a context, fixing some as premises, and making a series of inferences, then drawing conclusions. These conclusions are called *information* but do not become *knowledge* if they are not related to the knowledge and experience of a specific person.

Davenport & Prusak (1998) stated that knowledge is the combination of data and information, to which is added the opinion of expert persons, competence and experience, to build a valuable asset that can be used to aid decision-making [4]. Knowledge cannot be lost in the same way in which one can lose data and information. In the domain of competence, as shown by Rowley (2007), the more to move from data to knowledge, the greater is the dependence on the context [19]. Knowledge is always individual and cannot be transmitted because it is generated from the individual's previous experience and knowledge; what one can transmit is only the narration of the experience.

Wisdom is immaterial, intangible. Wisdom is the judgement, the ability to add value and is unique and personal. Wisdom is something that goes beyond the concepts of information and knowledge and embraces both, assimilating and transforming these into individual experience. Wisdom accompanies knowledge and allows to make the best choices.

The traditional DIKW model is an attempt to categorize and simplify the key concepts involved in cognitive processes, especially when there is a need to manage large amounts of data. This theoretical model provides a hierarchy, consisting of a very large base of raw data, which, going towards the top of the pyramid, is subject to an aggregation–contextualization process, i.e., information, and application testing, i.e., knowledge. On top of the pyramid is confined wisdom, which assumes a level of knowledge that is beyond the scope of a specific application. These cognitive states are then connected in a hierarchical manner, assuming that between them there can be a smooth transition from the bottom to the top [1, 2, 4, 19].

As in the case with all models, the DIKW model has its limits [8, 10, 14, 15]. The authors suggest the model is quite linear and expresses a logical consequence of steps and stages with information being a contextualized "progression" of data as it gets more meaning. Reality is often a bit different. Knowledge, for instance, is much more than just a next stage of information. Nevertheless, the DIKW model is still used in many forms and shapes to look at the extraction of value and meaning of data and information [19].

One of the main criticisms of the DIKW model is that it is hierarchical and misses several crucial aspects of knowledge and the new data and information reality in this age of IoT, Big Data, APIs and ever more unstructured data and ways to capture them and turn them into decisions and actions, sometimes bypassing the steps in the DIKW model, as in, for instance, self-learning systems [8, 13, 14, 15]. The data must be of a certain type to really add value to an organization. Big Data does not necessarily mean more information: the belief, rather widespread, that *more data = more information* does not always correspond to reality [14, 15]. Among Big Data, there are obviously interpretable data and data that cannot be interpreted (sometimes because of lacking metadata or place/time references).

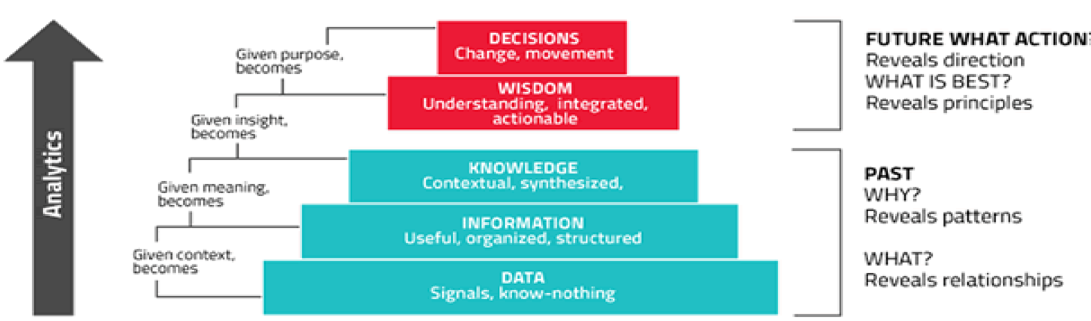

Figure 1. What matters: actions and decisions in the DIKW model

Among the interpretable data, there are relevant data, i.e., the signal, and irrelevant data, i.e. noise, for our aims [13, 14, 15, 16, 17]. So, a criterion to decide whether it makes sense to think of an analysis based on Big Data would be to think about the interpretability, relevance and whether the process could extract really new information from the mass of data. However, the essence stays the same: looking at what to do with data lakes and turning data through Big Data analytics into decisions and actions [18, 19], as shown in Figure 1.

The traditional DIKW model, as all models or ways of looking at things in a more or less structured way, has been discussed and looked upon from various angles with some suggesting to omit wisdom, others debating the exact definitions and the relationships between them and a few telling to add a dimension of truth and moral sense to it, with the addition of something even higher than wisdom: "enlightenment".

The authors suggest the traditional DIKW model as one of several ways to define, illustrate and explain the various forms of data, information, etc. in a business, transformation and customer/stakeholder perspective. They have nothing against enlightenment as a step beyond wisdom, usually defined as "evaluated understanding" or "knowing why", which they would then call truly understanding the purpose of information in a context of what people need and want, beyond the more factual knowledge. The enlightened business? Who knows. The traditional DIKW model is also mapped to different types of management information systems. For instance, data is related with transaction processing systems; information with information management systems; knowledge with decision support systems; and wisdom with expert systems. What the authors are most interested in, is the decision and action part, because without decisions and actions there is little sense in gathering, capturing, understanding, leveraging, storing and even talking about data, information and knowledge. The authors mean the decisions and actions as in business and customer outcomes, creating value in an informed way. However, in the bigger picture, the authors state that the decisions and actions can simply be learning, identifying, evaluating, computing or anything else.

Effects of IoT and Big Data to knowledge-based management practices. Organizations use information and knowledge both for improving the quality of decisions and for legitimizing decisions including also decisions made by poor knowledge [2, 4]. The authors consider that organizations often fail to use information in an effective way in decision-making because of the oversupply of information, caused by biased organizations incentives for information in result of tendency to underestimate the costs of information gathering relative to its benefits. Typically, decisions about information are made in a different part of an organization than where the actual information gathering is conducted. This separation of using and gathering information enable managers to initiate information gathering process that may have value for them, but from the organizational perspective create more costs than benefits. This kind of behavior is rational for managers as it creates an illusion of managing uncertainty [2, 4]. Rationality of information oversupply relates also to strategic value of information. This can be seen in cases where information is not, in the first place, used for doing sound decisions, but for persuading someone to do something. Despite of increasing academic, as well as practical efforts, there is a difference in views on knowledge in decision-making either seen as a static asset owned by an organization or as a social construction emerged from interaction. Static view on knowledge implies the manageability of knowledge, where as social view emphasizes that knowledge cannot be managed, only enabled. Static view treats knowledge as object that can be identified and handled in information systems, when social view deems the role of IT as useful but not critical because it emphasizes assessing, changing and improving human individual skills and behavior.

Related to differences in the role of IT, including IoT and Big Data, the two views on knowledge have also contributed two different KM strategies. The authors evaluate possibilities that come along with the emergence of IoT and Big Data. Do IoT and Big Data lay down a basis for more smart, intelligent and even wise decision-making? Do IoT and Big Data bring knowledge-based decision-making into higher level? In order to reflect on these questions, the authors have had to analyze the functions of knowledge and information in decision-making. One possible useful approach to analyzing decision-making is defining it as a moment which divides time into two eras, before and after decision. It is important to recognize that while decisions fulfill expectations they simultaneously produce insecurity in the sense that it becomes obvious that a different decision could have been reached. To manage uncertainty-related decision-making, organizations need information and knowledge to convince internal and external stakeholders that choices are made rationally. Although, conflicting interests and problems of gathering the all relevant information means that rationality in decision-making is only bounded. The authors suggest that by information and knowledge it is possible to create an impression of rational and reasoned behavior, which, in turn, contributes to internal trust and to preserved external legitimacy. This means that sound knowledge before decision also helps the implementation of decisions. It is also good to understand that the problem of bounded rationality is key motivation for organizational foresight activities. The discussion shows that information is gathered and knowledge used both for improving the quality of decisions and for mitigating potential decision consequences. Occasionally organization's knowledge behavior is based on rationalistic ideal, whereas sometimes it is highly symbolic. Adopting the conventional view of IoT and Big Data, the authors suggest that the true value of IoT and Big Data in decision-making lies on their ability to simultaneously promote bounded rational behavior, i.e., provide the best possible information and to limit symbolic use of information, i.e., oversupply of information that have no value in improving decision's quality.

More generally, the authors assume that IoT and Big Data predict the new start of knowledge management and the revision of the traditional DIKW model. Perhaps, the division of KM strategies into codification and personalization strategies should also be reconsidered. For instance, Jennex & Bartczak (2013) state that society and organizations manage by planning [10]. Resources are limited, time is limited, and planning applies thought before action. The output of planning is a plan or strategy, a statement of how something will be done. Society and organizations need to have a strategy for managing the layers and technologies, including IoT and Big Data, in the revised DIKW model. Jennex & Bartczak (2013) suggest the basic components of a KM strategy can be generalized and used to manage decisions and actions in the revised DIKW model, including identification of users of the knowledge pyramid layers and transformation processes; identification of actionable intelligence needed to support organizational/societal decision-making; identification of sources of the Big Data, data, information, and knowledge; identification of Big Data, data, information, and knowledge to be captured; identification of how captured Big Data, data, information, and knowledge is to be stored and represented; identification of technologies, including IoT, to be used to support capturing and processing Big Data, data, information, and knowledge; generation of top management support; establishment of metrics, as well as feedback and adjustment process on the effectiveness of actionable intelligence use. Jennex & Bartczak (2013) conclude the goal is a top-down strategy approach based on decisions and actions [10]. The authors also note the digital revolution in management process, by developing and utilizing smart solutions like utilization of IoT and Big Data, impact strategies based on decisions and actions as in business and customer outcomes, creating value in an enlightened way [13, 14].

3. Practical view on IoT-driven eHealth

3.1 Analysis of a case study on improving the patient discharge planning process through knowledge management by using IoT

Background. The UK National Health Service (NHS), a publicly funded organization, provides healthcare for all UK citizens (currently more than 62 million people) [17]. The NHS is faced with problems of managing patient discharge and the problems associated with it, such as frequent readmissions, delayed discharge, long waiting lists, bed blocking and other consequences. The problem is exacerbated by the growth in size, complexity and the number of chronic diseases under the NHS. In addition, there is an increase in demand for high quality care, processes and planning. Effective Discharge Planning (DP) requires practitioners to have appropriate, patient personalized and updated knowledge to be able to make informed and holistic decisions about a patients' discharge. The NHS case study examines the role of knowledge management in both sharing knowledge and using tacit knowledge to create appropriate patient discharge pathways [11]. It details the factors resulting in inadequate DP, and demonstrates the use of IoT and Big Data as technologies and possible solutions that can help reduce the problem. The use of devices that a patient can take home and devices that are perused in the hospital generate information that can serve useful when presented to the right person at the right time, accordingly harvesting knowledge. The knowledge when fed back can support practitioners in making holistic decisions with regards to a patients' discharge.

The current DP dilemma in the NHS. Discharge is defined as when an in-patient leaves an acute hospital to return home, or is transferred to a rehabilitation facility or an after-care nursing center. DP should commence as early as possible in order to facilitate a smooth discharge process [17]. Discharge guidelines have been prescribed by the UK Department of Health (DH) and different trusts implement discharge pathways or process maps following these guidelines. Several DP improvement attempts have been made and reasonable improvements have been noticed. Several methods by which DP takes place have been identified in two UK hospital trusts, including DP commences on admission: patient and care giver are involved in the decision-making process; a clinical management plan where an expected date of discharge is predicted based on actual performance in the ward or, on benchmarking information from past cases; multidisciplinary teams make a decision based on experience during their meetings. A bed management system stores information on beds occupied and weekly meetings are held to decide the discharge date for patients. All of these methods involve KM. It is seen that, a rough DP is currently drafted for patients upon entry to hospital according to their diagnosis, and a tentative discharge date is provided in line with recommendations. Changes are made over the course of the patient's stay and records are manually updated by nurses, upon instruction by the doctors. This sometimes results in confusion and even disagreement on discharge dates by different doctors (i.e., when treating the patient for different symptoms) and nurses (i.e., when a change of shift occurs). This case study proposes that patient DP requires viewing the whole system and not as isolated units. In the discharge plan the patient and care giver involvement needs to be considered, however very little indication has been provided on these. To date, clear guidelines are not present on what information needs to be collected, stored and reused on patients.

Analysis by the authors. The UK NHS is facing problems of managing patient discharges while having to meet waiting time, treatment time and bed usage targets. Patient discharge is currently being driven by quantitative measures such as targets (e.g. to reduce "bed-blocking") and problems resulting from this situation has received a great deal of popular press attention recently and political capital has been made from this. Targets are prioritized while compromising patient's after-care quality. Being target-driven (rather than knowledge driven) implies that the healthcare system fails to consider the factors that affect the effective recovery of a patient after treatment and discharge. Hospitals focus on accomplishing and achieving internal targets, resulting in compromised patient safety and well-being after discharge. The exact situation with regard to patient discharge and readmissions is not really well established, as there are variations in discharge methods between trusts. However, it is reported in the popular press that doctors have to make quick decisions about patients just to "get the clock to stop ticking" resulting in deteriorating trust between doctors and patients. More precisely, doctors find themselves torn between meeting targets and providing their sick patients with the best treatment. These claims in the assorted news media have been reaffirmed by Andrew Lansley, the Secretary of State for Health in the UK Government. "The NHS is full of processes and targets, of performance-management and tariffs, originally, all designed to deliver better patient care, but somewhere along the line, they gained a momentum of their own, increasingly divorced from the patients who should have been at their center." (Guardian, 7 December 2012). Several factors result in the current inadequate DP. These factors are internal and external to the NHS along with psychosocial factors of patient and family. It is important to understand the factors behind inadequate DP to be able to analyze and identify the factors causing the problem systematically [11]. A comparison can then be made between the factors along with the results obtained from the case study, followed by a catalogue of possible solutions underpinned by KM. This will then lead to making a diagnosis, i.e., the proposed KM model [11]. A Root Cause Analysis (RCA) highlights the factors contributing to inadequate DP as shown in Figure 2, and demonstrates the patient discharge as a complex process, with various interrelated factors [11].

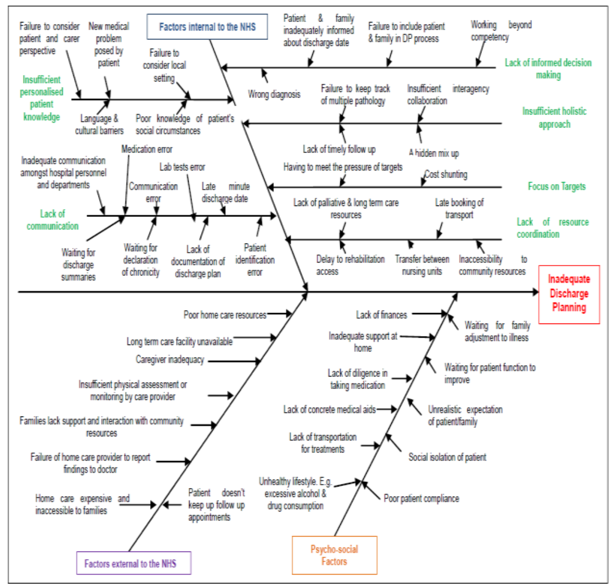

Figure 2. RCA of factors resulting in inadequate DP.

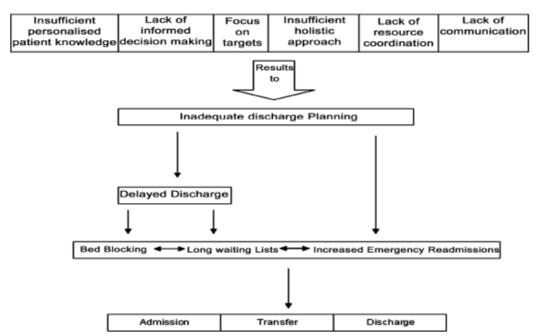

Figure 3. Problems resulting from inadequate DP.

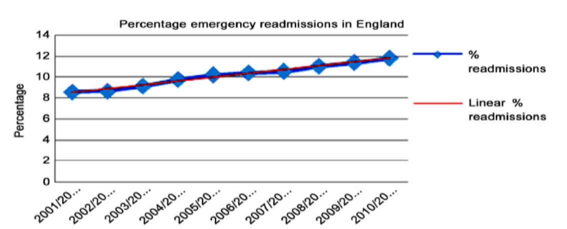

Figure 4. Emergency readmissions in England as percentage of admissions.

A carefully designed DP supported by KM can ensure more efficient utilization of hospital resources and will encourage better inter-department communication to ensure that tacit knowledge makes better informed decisions about patient discharge. It is believed that this in turn will allow for better coordination of the external factors and will give hospital personnel more time to inform patients and their families, accordingly addressing the psychosocial factors. At discharge, preventable and undetected errors can occur. These can be reduced by knowledge sharing among hospital staff and having patient centric discharge pathway leading to improved DP. Patient participation and understanding in DP will help reduce potential readmissions and delayed discharge. Patient participation in the discharge process is a legally stated right in the UK and therefore more active participation of patients is encouraged. The failure to assess a patient's care needs correctly can result in a disproportionate delay in patients being discharged.

The problems caused by inadequate DP have been identified [11] and summarized succinctly in Figure 3. The number of patients readmitted to hospitals through Accident and Emergency (A&E) departments within 28 days of being discharged has risen steadily from 359,719 in 1998 to 546,354 in 2008, while in 2010 more than 660,000 patients were readmitted to hospital within 28 days of discharge. According to statistics provided by the Department of Health, in England in 2010-2011 the total number of patients who were readmitted was 561,291. According to the statistics, readmission rates in England have been rising since 2001-2002 to 2010-2011. Figure 4 follows the increasing trend of the percentage of patients readmitted for treatment to UK acute hospitals within 30 days of discharge and a "line of best fit" shows the regularity (and therefore the predictability) of the rise.

The problem of inadequate DP does not just concern readmissions, however. "Bed-blocking" due to delayed discharge has equivalent negative implications. It is reported by the NHS confederation that one in four patients are occupying beds when they could be recovering at home, which results in longer waiting lists, loss of confidence in the NHS and escalating expenditure. The average number of patients and days of delayed discharge per month in England for the year 2012 according to the Department of Health was 3997 patients and 114,386 days respectively. Approximately £250m was spent on "delayed discharges" between August 2010 and the end of 2011, amounting to £550,000 a day. Apart from the financial implications the delay in discharge is clearly disadvantageous to the well-being of patients, the morale of their relatives and wastes valuable hospital resources. The King's Fund reports that if it was better organized the NHS could reduce the number of overnight stays by 2.3 million, freeing up 7000 beds and saving the NHS nearly £500m a year. Mike Farrar, the Chief Executive of the NHS Confederation, indicated that these problems are the result of an "outdated hospital model of care" while a breakdown in communication may also be a possible contributory cause. Many older patients face the brunt of delayed discharge as due to a lack of communication between the NHS and social care homes, they are forced to stay in hospital, causing longer waiting lists for other patients who are seeking urgent treatment. The reasons for the dilemma as described in the case study are clearly a result of inadequate support for DP among NHS staff, including physicians, nurses, social workers, and possibly other health professionals.

KM for successful DP. A hospital is a dynamic environment, with changes taking place rapidly as patients move from one ward to another and treatments are carried out over time. Similarly, DP involves changes from a stable temporal state to another with an element of unpredictability of what is going to happen next. In this context the past experiential knowledge of doctors and nurses is useful in assessing situations and deciding on plans. This enables making critical decisions, as their knowledge can be reconfigured and extended to fit the new situation and provide a personalized approach in assessing patients' journey along codified guidelines. KM may have the potential to remove bottlenecks to improve the DP process mapping and identify possible improvement opportunities. Understanding the relevant knowledge for a given situational decision is crucial to this process and a decision can never be completely separated from the context in which it is made. This implies that in a hospital setting when looking at DP the interrelated factors need to be considered in the context of KM process [11]. Clearly, monitoring and understanding a patient's condition after discharge is a key part of successful DP. This requires the support of appropriate sensing and monitoring technologies with IoT and Big Data [13] (i.e., medical equipment; patient monitoring systems; smart devices supporting per-signalization such as Lifeline Home Units, Personal Pendants, Wandering Client Alarms, Automatic Pill Reminders and Dispensers, Fall Detectors and Bed Occupancy Sensors), so that patients with chronic conditions are able to live independently in their own homes or secure housing (i.e., a non-hospital setting).

IoT in eHealth. Although the authors prefer to use the term IoT for integrating so far not communication-able devices into a digital, communicating infrastructure (often based on the internet infrastructure and services), they hereafter include communicating sensor and actuator devices, aimed at measuring and, where applicable, controlling health-relevant parameters [6].

IoT as enabler. The technological development of direct and indirect sensor systems, and miniaturization, are making available ever more IoT sensor systems [11, 13] that could make practical use in eHealth possible, and, thereby, eHealth feasible and accessible.

Gadgets and medical relevance. Most of these sensors require positioning and sophisticated and medical knowledge-based algorithms to make them medical-relevant. In absence thereof, unfortunately, they stay gadgets with a merely indicative value for healthy living and exercising. Moreover, smart applications and algorithms, using the facilities of the current generation smart phones, in particular accelerometers and cameras, have created another wealth of healthy living and exercising APPs, with even more limited medical relevance [6, 13].

Dynamic EHR and dynamic EPHR. The grand vision of Electronic Health Record (EHR) infrastructures is the interconnection and reusability of all recorded health information, regardless of where it is stored, so that all relevant health information can electronically flow to wherever it is needed. Nothing will become of this vision, however, unless critical privacy and security problems are overcome. IoT devices, if designed and used to support medical applications, may become part of a *Dynamic* Electronic Health Record (EHR) or a *Dynamic* Electronic Personal Health Record (EPHR), where IoT may be used to provide the on-line, dynamic, very recent past complement to the static EHR and EPHR stored information, as well as a tool in support of security mechanisms [9, 12, 20].

System approach versus "whatever" approach. In order for IoT to make an important and necessary contribution to eHealth, a system approach needs to be followed, not a "whatever" approach, as is too often the case with today's wearables [6, 13]. In a number of the companies and research organizations in the world, there is the infrastructure and multi-disciplinary competence, necessary to develop IoT-based medical-relevant eHealth systems, as is shown by the laboratory prototypes, such as continuous, real-time blood pressure monitoring systems; and by pre-production prototypes, such as diabetes insulin control systems.

3.2 A qualitative evaluation of IoT-driven eHealth

eHealth requirements. Eysenbach (2001) gave a set of requirements, such as the ten plus "e's" in eHealth [7]: the "e" in eHealth does not only stand for "electronic", but implies a number of other "e's," which together perhaps best characterize what eHealth is all about: efficient; enhancing quality of care; evidence-based; empowering consumers and patients; encouraging a true partnership between patients and health professionals; educated; enabling data and information exchange and communication between health care establishments; extending the scope of health care beyond its conventional boundaries; ethical; and, also, equitable. In addition to these 10 essential e's, eHealth should also be easy-to-use, entertaining (pleasant), exciting, and… it should exist! Refining this top-down, but less detailed view gives a number of requirements for eHealth, which are defined below [2, 13, 15]. Medical and/or care relevant and usable systems require collection of medical relevant data with direct and indirect practical measurement. They represent compromise between user/patient comfort and data collection quality and reliability and consist of suitable sensors used in a way matching the capabilities and limitations of the sensors. Data pre-processing requires data reduction to avoid data overflow and generation of reliable warnings (alarms) to make use of data manageable and beneficial. Data interchange and exploitation is required in combination with other IoT and non-IoT data, e.g., location information; security and privacy; trust and reliability; anonymization of data where possible; as well as on-line and off-line data post-processing with medical relevant objectives. System approach versus "whatever" approach requires the users (patients), who are active committed stakeholders/beneficiaries; the medical and care providers, who are committed stakeholders (beneficiaries); and the infrastructure and service providers, who provide installation, operations, maintenance and repair. It assumes the IT infrastructure, which includes middleware, cloud storage, cloud processing and applications; the near/on-user/patient systems and smart systems. Besides, it requires the compromise between patient benefits versus black-box/post-mortem benefits and hybrid/dialogue development approach with the top-down requirements and the bottom-up possibilities. Finally, it should be cost-benefit-driven.

eHealth limitations. For the foreseeable future, eHealth will not replace doctors, medical experts and care providers. Instead, it must be a joint tool used together between users (patients) and eHealth professionals for the benefit of both, and this has to be fully taken into account in the development and deployment. Besides, the limitations below must be considered. These limitations include the patient benefit versus black-box/post-mortem approach as it simplifies recording effects of a disease or condition instead of preventing or curing it; along with applying negative evidence gathering, e.g. non-compliance with the prescribed diet and medication instead of directly contributing to overcoming an illness or condition. The limitations also include generating warnings and alarms that are essential for the usefulness of eHealth, without risking eHealth to become the black box of Health. In its place, generating warnings and alarms is as good as the quality of the data collection and the applied algorithms; therefore, applying AI and Big Data techniques may be helpful post-processing options. However, the absence of warnings and alarms can never be taken as guarantee for the absence of risks and conditions. The unjustified cost-saving expectations, meaning the cost of installation, maintenance, technical and medical healthcare operation should be taken into consideration, already in the system design and planning phase. Additionally, it may be easier to achieve better quality health care than achieving real cost reductions.

eHealth entry barriers. Before eHealth becomes widely implemented and adopted, there are a number of barriers to overcome. The main barriers are based on functionality, which includes medical relevant data and information, time needed to accept and develop procedures and algorithms and AI to handle the reduce data, obtain information and generate reliably warnings and alarms, trust, security and privacy. Security and privacy concerns are major impediments to eHealth because if they are not properly addressed, healthcare seekers won't feel comfortable in participating, and healthcare professionals will face huge liability risks. Additionally, the entry barriers include usability and "companionship" for both users/patients and healthcare providers along with market development and the required stability in value chains and business plans.

eHealth security and privacy concerns. Although the authors prefer the more general terms, such as Data Ownership and Access Control [9], they mainly use the more familiar terms Security and Privacy [5, 20]. Developing and implementing security and privacy functions in eHealth is a prerequisite for adoption by both users/patients and healthcare providers. It concerns, however, a more complex ecosystem than environments currently addressed, requiring new and more sophisticated privacy and security systems, that in turn may be used in other more demanding applications, i.e., in Industry4.0, energy, social networks [18]. In particular, the requirements include individual privacy, temporary and permanent sharing of subsets of private information, user controlled access between providers, transferring ownership from a provider to the user or another provider, role-based access, etc., and, a controlled and regulated "break-glass" function for emergency situations [3, 20]. The authors state that while security is related to privacy, the two concepts are quite different. The Health Insurance Portability and Accountability Act of the United States (HIPAA) and the Organization for Economic Co-operation and Development (OECD) clearly distinguish between security and privacy. The eight Fair Information Principles codified in 1980 by the OECD are openness; collection limitation; purpose specification; use limitation; data quality; individual participation; security safeguards; and accountability. Security safeguards constitute only one of the eight principles; they are necessary to achieve privacy, but not sufficient. In fact, most real life threats come from "secondary use" by insiders with authorized access.

4. Business models and opportunities, deployment and evolution.

While eHealth has a major potential and it adoption may even be considered necessary to achieve increased ambulant and remote medical care, increased quality of care, reduced personnel needs, and reduced or reduced increase in costs, the market is not developing as hoped and expected. Predominantly vertical markets have developed explosively for fitness, sports and healthy living. Their contribution to eHealth is limited, however, and the value chain less suitable for an eHealth market development. It is, in particular, the unsettled configuration of the value chain that create an uncertainty in the eHealth market, or better markets, as the parameters may be different between countries or even regions, therein the separation and/or overlap between private and public health services provision; the separation and/or overlap between private and public health services insurances; the role of telecom and communications services providers; the role of equipment manufacturers; the role of equipment and communications services installation and services companies. "Asymmetries" in the value chain create a separation between costs and benefits and overlapping and/or crossed responsibilities, potentially putting investments needed and benefits at different entities in the value chain, such as investments made near the user/patients would contribute to cost savings in a hospital; and investments made in a hospital would contribute to cost savings in the public social sector. The unsettled configuration of the value chain results in uncertainty for the scope and hence of business plans. And this uncertainty in the value chains and business plans do not favor the commitment and market development, in turn leading to low interest from industry, hesitant telecom service providers and manufacturers in joint research and development and standardization, essential to arrive at coexistent and interoperable infrastructure and support for common generic and specific applications. Whereas telecom providers try to offer "premium services" for eHealth services, it could be observed that few eHealth applications require high bandwidth, low delay, low Bit Error Rate (BER) services. Instead, eHealth requires rather a reasonable high availability including a short time to repair, 24/7. And strangely enough, while eHealth, and in fact, our whole society becomes more and more dependent on access to the internet and the services it supports, the availability of networks and Quality of Services (QoS) is not improving, but rather degrading. This may lead to the development of communications service providers that guarantee a service covering support for eHealth equipment and high availability telecom services to address this gap. The time necessary for organizations to arrive, alone or together with partners in the value chain, to decisions to invest and deploy eHealth systems at a large scale is often not sufficiently taken into account or even ignored. As, in particular, deployment takes a significant amount of time, and technological development keeps it pace, it is predictable that organizations applying eHealth systems will be working in parallel with several generations of equipment, using several generations of the telecom infrastructure (2^{nd}-, 3^{rd}-, 4^{th}-, 5^{th}-generation WAN, Lora, satellite, etc.). Regarding the functionality, it may be expected that eHealth equipment will develop into fully or partially implanted systems, with an increasingly feedback and control functions.

5. Conclusion

This paper examined theoretical and practical views on IoT-driven eHealth. Theoretical view concerned associated knowledge management issues. The authors studied the problem of patient readmission into hospitals and recommended ways of reducing readmissions through improved discharge planning process with KM by using IoT and Big Data, to prove a strong connection between KM and IoT-driven eHealth. The IoT and Big Data were proposed to enforce knowledge sharing. Practical view concerned potential contributions of IoT to eHealth, deployment and evolution. The authors concluded that IoT-driven eHealth can and will happen; however, much more needs have to be addressed to bring it back in sync with medical and technological developments in an industrial state-of-the-art perspective, and to get recognized and get timely the benefits.

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