What Are Complex eHealth Innovations and How Do You Measure Them?

Position Paper

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Summary

Objectives: eHealth and innovation are often regarded as synonyms – not least because eHealth technologies and applications are new to their users. This position paper challenges this view and aims at exploring the nature of eHealth innovation against the background of common definitions of innovation and facts from the biomedical and health informatics literature. A good understanding of what constitutes innovative eHealth developments allows the degree of innovation to be measured and interpreted.

Methods: To this end, relevant biomedical and health informatics literature was searched mainly in Medline and ACM digital library. This paper presents seven facts about implementing and applying new eHealth developments hereby drawing on the experience published in the literature.

Results: The facts are: 1. eHealth innovation is relative. 2. Advanced clinical practice is the yardstick. 3. Only used and usable eHealth technology can give birth to eHealth innovation. 4. One new single eHealth function does not make a complex eHealth innovation. 5. eHealth innovation is more evolution than revolution. 6. eHealth innovation is often triggered behind the scenes; and 7. There is no eHealth innovation without sociocultural change.

Conclusions: The main conclusion of the seven facts is that eHealth innovations have many ingredients: newness, availability, advanced clinical practice with proven outcomes, use and usability, the supporting environment, other context factors and the stakeholder perspectives. Measuring eHealth innovation is thus a complex matter. To this end we propose the development of a composite score that expresses comprehensively the nature of eHealth innovation and that breaks down its complexity into the three dimensions: i) eHealth adoption, ii) partnership with advanced clinical practice, and iii) use and usability of eHealth. In order to better understand the momentum and mechanisms behind eHealth innovation the fourth dimension, iv) eHealth supporting services and means, needs to be studied. Conceptualising appropriate measurement instruments also requires eHealth innovation to be distinguished from eHealth sophistication, performance and quality, although innovation is intertwined with these concepts. The demanding effort for defining eHealth innovation and measuring it properly seem worthwhile and promise advances in creating better systems. This paper thus intends to stimulate the necessary discussion.

1. Introduction

1.1 Motivation

Innovation, including eHealth innovation, is often regarded as something fancy, impressive, and immediately convincing. This understanding is misleading and may have distorting effects on the appraisal of a new development as innovative and on innovation measurement. The aim of this paper is, therefore, to explore the nature of eHealth innovation against the background of findings in biomedical and health informatics. Seven facts are derived from the literature and presented for stimulating a comprehensive discussion on the relationship between eHealth and innovation and on methods for how to properly measure complex eHealth innovation.

1.2 eHealth and Innovation

eHealth has become a synonym for the use of information and communication technology in healthcare within and across settings and disciplines [1]. Electronic nationwide infrastructures, electronic health records (EHR), telemedicine, ePrescription, and eDischarge are examples of networks, systems, and services that are typically targeted by eHealth [2, 3].

While the technology perspective has dominated eHealth in its first years, the perspective has shifted towards applications and meaningful use – in particular of EHR systems – recently [4]. The meaningful use debate has undeniably given eHealth further strong momentum towards sharing data, advancing clinical processes, and improving the outcomes of clinical services [5]. It makes it clear that, today, sup-
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3.1 Fact 1: eHealth Innovation Is Relative

Novelty is often regarded as a relative term in the context of innovation, dating back to Rogers who defined innovation as “an idea, practice, or object that is perceived as new by an individual or other unit of adoption” ([9] p. 12). Innovation can, therefore, be an innovation just for a single organisation, a group of organisations, for a country, or it can be a worldwide innovation. Due to this definition, adoption is an inherent prerequisite of innovation.

In this sense, it is justified to measure eHealth innovation at different levels of adopters. It thus can be measured at the level of single adopters by asking them about the perceived novelty of dedicated eHealth innovations that they had adopted. eHealth innovation can also be identified with regard to a group of adopters. In this case, an eHealth development is regarded...
as innovative if it was adopted by a small group only. This minority can then be classified as early adopters pertaining to their adoption behaviour of a specific development. Again, this is a relative measure. In the context of IT benchmarking innovative behaviour and innovative eHealth objects can be studied with regard to a reference group of comparable characteristics [21]. In the context of national surveys, eHealth innovation can be measured at the level of an entire country of adopters [22]. Innovative behaviour of an organisation and innovative eHealth objects can be identified similarly to the comparison within a reference group. In multinational surveys, innovation is defined relative to the participating countries and their organisations as potential adopters.

eHealth innovation is also relative in terms of the stakeholders within an adopting organisation [25]. To account for the conflicting needs between medical specialties [26] and stakeholder priorities and interests [27] views of different professional groups and the patients have to be captured and quantified.

**Example 1: The rural vs. urban view**
McCullough and colleagues [28] analysed the adoption of health IT according to the criteria of Meaningful Use Stage 1 based on the data set of the IT survey of the American Hospital Association. They distinguished between two types of rural hospitals and contrasted their data with those of an urban hospital. According to their study, rural hospitals had significantly lower adoption rates in nearly all criteria at the time of measurement. For example, while two thirds of urban hospitals had implemented the function “electronic access to diagnostic test results” only less than one quarter of type 1 rural hospitals had this function available.

Thus, a rural hospital that had integrated the feature “electronic access to diagnostic test results” would be innovative relative to the peer group because only few others were in a similar position. However, an urban hospital with the same feature would be regarded as less innovative because a large majority of hospitals already had been equipped with the same function.

**3.2 Fact 2: Advanced Clinical Practice Is the Yardstick**
eHealth is an enabler for achieving information continuity: along the entire care trajectory, within dedicated services, e.g., the treatment by a health care provider within a defined care episode, e.g. radiology, or within larger clusters of clinically meaningful tasks, e.g. the admission process or the discharge process. eHealth innovation can thus be measured by its fit to clinically meaningful processes and services. However, these processes and services are evolving themselves and hence are a moving target. There are many driving forces to improve these processes and services, e.g. patient safety [29], quality of care [30], patient centred care [31–33]. Thus, when measuring the match between innovative eHealth technologies and processes and services, advanced clinical practice must become the yardstick. Advanced clinical practice is hereby defined by its results and, in fact, as clinical processes leading to proven superior health outcomes than the usual care processes. eHealth innovation, therefore, must prove its contribution to advanced processes and transforming and enhancing current clinical practice to become more advanced. Consequently, the measurement criteria for defining the match between eHealth innovations and good processes and services have to be regularly adjusted.

Thus, for eHealth innovation to become measurable in detail and to show the exact fit, IT-infrastructure, systems including their architecture, functions, and data elements must be systematically matched to these advanced processes and services. The 3LGM², for example, is a methodology to model, visualise, and analyse seamless IT systems and contributed to implementing advanced processes and services, advanced clinical practice and used. However, making “use” a criterion for innovation neglects the fact that something new is sometimes used only because its use is made mandatory by the organisation for all employees. “Use” must be, therefore, coupled to “usability”.

Due to the technical nature of eHealth, any type of eHealth innovation – not only product innovation – will be shaped significantly by some sort of eHealth system, either new or existing or both. This system and its implementation can be designed properly and fulfil its purpose well or it can have flaws and lead to a reduced usability. There is broad evidence that unusable systems are not safe and induce errors [36]. In this light, not only the adoption and use of an eHealth innovation has to be measured but also its usability. Usability measures, in particular the metrics of task technology, fit, and task orientation, are strongly related to measuring the IT support of clinically meaningful processes and services. Due to the fact that different stakeholders

**Example 2: A patient-centred way of increasing compliance in prevention**
Lau and colleagues [35] conducted a randomised controlled trial (n = 742) on the effect of a personally controlled health management system (PCHMS) on the uptake of influenza vaccination and the utilisation of the health services of a university hospital. The PCHMS comprised care pathways for consumers that contained knowledge on the disease and information on preventive actions, here vaccination. Care pathways could create personalised entries in a personal health record and could book appointments at the hospital for vaccination and other services online. The PCHMS intervention group had a significantly higher vaccination rate and more health service utilisation than the waitlist control group.

The PCHMS supported a clinically meaningful service, i.e. influenza vaccination, and contributed to implementing advanced care processes, here effective consumer controlled health management. In meeting both of these criteria, this PCHMS can, therefore, be regarded as innovative.

**3.3 Fact 3: Only Used and Usable eHealth Technology Can Give Birth to eHealth Innovation**
Novelty is a necessary but insufficient condition for innovation. Bearing in mind that a potential innovation must have a positive impact on the performance of the organisation, something has the chance of becoming an innovation only if it is put into practice and used. However, making “use” a criterion for innovation neglects the fact that something new is sometimes used only because its use is made mandatory by the organisation for all employees. “Use” must be, therefore, coupled to “usability”.

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may have different views about what is an innovation (see Fact 1), multiple perspectives need to be captured when measuring complex eHealth innovation. Ultimately, it is the clinicians or more broadly the users who have the final say on whether eHealth is really helpful in performing their tasks and thus is innovative.

Example 3: A multi-professional EHR and the silos of healthcare
Tener and colleagues [37] analysed the predefined headings of existing templates implemented in a multi-professional EHR system, which was used in a fully-fledged version in four of five healthcare service divisions of a Swedish County Council. These headings constituted part of the clinical terminology within the EHR and thus built the foundation for searching in the system. The terms used related to a large group of health professionals including, amongst others, physicians, psychologists, registered nurses, medical social workers, and different types of therapists. The authors found that all professional groups shared only 1.7% of these headings. 59.3% of the headings were not shared at all. The authors argued that “specialist terms” warranted high mutual understanding and low ambiguity within a group but did not contribute to the aim of a multi-professional approach, i.e. a joint language for specific purposes. They concluded that more attention should be put on enhancing the quality and usability issues of multi-professional EHR systems. Multi-professional EHRs are highly innovative when they are usable and help to fulfil their clinical task, i.e. to overcome existing silos in healthcare.

3.4 Fact 4: One New Single eHealth Function Does Not Make a Complex eHealth Innovation

eHealth innovation aiming at processes and services are complex innovations. With this in mind, a new function implemented in a single new product may have difficulty showing that it affects the processes of an organisation because it seldom can work on its own. This could be shown, for example, by the limited benefits of blood pressure telemonitoring due to a lack of integration with the provider EHR [38] or by the missing effect of a stand-alone handheld medication management system on the reduction of drug-drug interactions [39]. Given this, evaluation studies often target multifunctional integrated systems, such as EHRs, Computerised Provider Order Entry (CPOE) systems or Clinical Decision Support Systems (CDSS) [40, 41] to demonstrate the impact of eHealth systems.

Based on the notion of eHealth as a combination of a multitude of systems, of functions and of data elements a group of scientists from the Nordic countries defined eHealth indicators that embrace EHR, Health Information Exchange, Personal Health Records and telemedicine both in terms of their availability and use [42]. These indicators have been matched with OECD indicators and constitute the content of the model OECD eHealth survey [43]. A view encompassing multiple systems, functions, and data that is spanning settings allows eHealth to be judged by its contribution to providing an information thread to lifelong care, to care episodes and clinical processes and services.

Functional interaction in a complex eHealth system requires first and foremost interoperable systems to demonstrate integration sophistication [44] and to warrant high quality information processing through the use of IT standards and data protection and security measures [45].

Example 4: Next generation EHRs concepts look at broad not incremental improvements

Saleem and co-authors [46] interviewed 14 health IT leaders of the Department of Veterans Affairs (VA) capturing the concepts that would drive the transformation of EHRs from electronic paper records to next generation records that exploit the opportunities of electronic systems. Pursuant to the interview results, eight broad themes could be identified: cognitive support in terms of interfaces, workflows and actionable cognitive support, information synthesis and sense making, teamwork and communication, interoperability, data availability, interface usability, customisation and managing information. The next VA EHR was regarded as a network of interoperable decentralised systems that was connected to where patient care took place, e.g. hospital, clinic, and home. Interview participants widely agreed to the need for further research and development in order to achieve these goals.

These eight themes give a good perspective on potential innovations in the EHR use and technical architecture. It is noteworthy that these themes address very generic targets that apply to any place in the entire organisation where health IT tries to improve the clinical work. The envisioned EHR systems are more than a mere collection of new functions; they aim at a fusion of information systems, humans, and their daily workflows.

3.5 Fact 5: eHealth Innovation Is More Evolution than Revolution

Innovation strives after breakthrough and change. The question is whether this aim is achieved in a revolutionary or an evolutionary style approach. Hammer and Champy argued in favour of a radical new design with a focus on processes in their book “Reengineering the Corporation” [47]. The reengineering wave also reached health care organisations, but with limited success due to the complexity of the processes [48], and consequently procedures leading through the various stages of change were recommended. Current reengineering projects that affect an entire organisation are planned and performed over a series of years. It could be demonstrated that this approach was successful with regard to clinical and financial criteria [49].

Taking into account the lessons learnt from reengineering, eHealth innovation should neither be expected to be implemented within a short time frame nor to immediately yield complete success. This evolutionary type of progress speaks in favour of applying maturity models of eHealth according to which the degree of innovation could be measured along a predefined maturity scale (e.g. [5]).

IT maturity models were derived from theory for the sophistication of hospital IT [44], from phase models for focussing different EHR safety issues [50], from empirical clustering for electronic medical records (EMR) sophistication [51] and were devel-
oped top down for the degree of ERM integration [52] and the implementation stages of electronic medical records [53].

The concept of dividing the evolution of innovation into phases may also be applied to the organisational uptake from adoption, diffusion, implementation, infusion, integration, normalization, and finally to routinisation [17]. The degree of routinisation and impact of complex eHealth interventions on the work processes and outcomes can be measured with the Technology Adoption Readiness Scale [54].

Measuring the evolution of eHealth innovation both in terms of technical features as well as uptake maturity is a matter of time and requires a longitudinal design and measurement instruments whose application is easily repeatable.

Example 5: The long run from resistance to relation

Takian and colleagues [55] studied the implementation of an electronic health record (EHR) system in a mental health hospital prospectively over a 30-month period. The hospital belonged to a group of early adopters of the English National Programme for Information Technology. Within this case study, the authors conducted in-depth interviews with internal and external stakeholders, undertook on-site observations and analysed the relevant documents to measure sociotechnical changing. They reported that in the phase shortly after the arrival of the EHR, negative attitudes concerning the system functions, performance, and workflows dominated the discussion. This mindset changed over time as the system was continuously used and finally benefits in terms of e.g. access to data, legibility of reports, transparency and use for research were well recognized. The authors concluded that there was no fast change from old to new but an ongoing transition from the traditional ways of doing things to EHR defined workflows.

The EHR system in this study was no new product as such but was innovative for this hospital and its staff, who had not been confronted with integrated health IT before. It took some time for the innovation to start enfolding its perceived benefits.

3.6 Fact 6: eHealth Innovation Is Often Triggered Behind the Scenes

Before eHealth innovation becomes manifest, visible, and thus measurable, technical and organisational facilitators take effect, or direct preparations take place in order to transform a generic eHealth approach into a specific eHealth innovation for this specific adopter. This holds true the more IT systems are involved [56], the deeper they are integrated and the better they intend to support care processes and services [57]. It is well known that for IT to contribute effectively to enterprise business processes it must be managed systematically. This notion has led to the development of holistic IT frameworks that provide a methodology for governing and managing IT related resources, structures, and services, of which COBIT and ITIL are the best known [58]. By systematising IT service processes they aim at improving the core processes of the enterprise. In COBIT 4.1, a process maturity model and a corresponding measurement scale are integrated, which were then extended to the COBIT 5 process capability model with grades from incomplete, performed, managed, established, predicted, and optimised IT processes [59]. This concept clearly interprets the progress of IT processes as evolutionary (see Fact 5) and underpins the notion that the preparation and continuous support of eHealth innovation is evolutionary itself. In addition, ITIL pursues an evolutionary understanding of IT management via its life cycle concept that is applied at all levels of IT services, i.e. strategy, design, transition, operation and continuous improvement [60]. IT governance not only exerted a positive influence on operational IT effectiveness but was also significantly associated with the mitigation of social and technical risks via an explicit risk management approach [61]. The authors contended that good risk management was needed in health care organisation with an entrepreneurial culture. Viewed this way, one may argue that the risks due to innovation can be kept at bay by good IT governance.

Although known in health care, IT governance and management approaches, such as COBIT and ITIL are still emerging methodologies for many health care institutions [62, 63]. IT governance and management can be considered a potential facilitator of eHealth innovation as well as an eHealth innovation itself and thus needs to be measured in conjunction with front end eHealth developments, i.e. those that directly affect patient care.

Whether IT governance and management actually foster eHealth innovation in any case is a matter of debate and may depend on the maturity of the eHealth systems concerned, i.e. IT governance and management may become door openers for innovation when few good eHealth systems are available but may have no effect once the systems fulfil the clinical needs.

Thus, metrics representing the existence and degree of IT governance and management must be investigated and more studies are required in order to obtain a complete picture of the antecedents of complex eHealth innovation.

Example 6: How are corporate governance and adoption of innovative IT interrelated?

Baird and colleagues [64] were the first to study IT innovation adoption and corporate governance in integrated delivery networks (IDN) in the United States. IT innovation adoption was defined as the percentage of barcode systems adopted for medication administration (clinical IT) and as a percentage of RFID adoption (supply chain IT). Both types of IT were regarded as innovative on the ground of low adoption rates. A series of regression analyses controlling for system size and ownership amongst others showed that the adoption of innovative clinical IT was negatively associated with IT centralisation and that the adoption of the innovative supply chain IT was significantly negatively related to alignment between IT and business goals of the IDN. Also the interaction between IT centralisation and alignment had a significantly negative relationship with the adoption of an innovative supply chain IT. The authors concluded that the strong centralisation of IT decision-making processes and that trying to fit IT to the overall business goals of a whole group of hospitals had a negative effect on the adoption of innovative systems.
More research in this field is needed because these findings only partly support the hypothesis of IT centralisation and alignment countering IT innovation. It would be interesting to apply this approach to more complex eHealth innovations.

3.7 Fact 7: There Is no eHealth Innovation without Sociocultural Change

One of the context factors that is paramount to the adoption of complex eHealth innovation is the involvement of the users and their appropriate training and education. It is, therefore, discussed separately. Missing user involvement has been identified as one of the problem areas already at the end of the 1970s, and that continued to be regarded as a problem area at the turn of the millennium [65] and user participation and training still persist as a high priority area calling for change [66]. It could be demonstrated that user involvement achieved by communication and overall responsibility was significantly related to creating psychological ownership of this system, which was in turn associated with a positive attitude towards the system and actual system adoption and use [67]. Moving along the path from adoption to the routinisation of eHealth innovation users and the interaction between users, tasks, and technology play an increasingly critical role. There are many potential obstacles along this path that can be turned into facilitators once they are known: those that are part of the organisation, e.g., supportive organisation culture for change, those that are part of the work force, e.g., IT experience and knowledge, computer self-efficacy and those that are part of the technology in conjunction with its users and related tasks, e.g., performance and effort expectancy and eHealth and business process alignment [68].

User involvement can be put into practice by many ways, e.g., by implementing the positions of the chief medical information officer [69] and their counterpart in nursing and by assigning key informatics tasks to these positions and their staff. Similar to IT governance and management, user involvement has a dual nature as an enabler of eHealth innovation and as a potential eHealth innovation in itself and needs to be measured with respect to this (see Fact 6).

Example 7: From user involvement to clinical leadership
Greenhalgh and colleagues [70] performed a secondary data analysis on factors promoting and inhibiting the adoption and use of nationally shared electronic record systems in England, Scotland, Wales, and Northern Ireland. In particular they looked at the influence of hard and soft factors in the context of the scope and set-up, system design, implementation process, promotion of acceptance and use and how the programmes were evaluated, monitored and learning took place. They concluded that whether or not the implementation of the programmes and the actual use of the systems were regarded as successful depended on a mix of personal, social, organisational, and technical issues. This also included the definition of “success” which differed across the programmes. The authors reported that success understood as a high rate of acceptance and good IT integration into current processes was associated with clinicians playing a central role and assuming the leadership as well as with early patient consultation. Sustainable innovation seems hardly possible without clinicians having a say.

3.8 Conclusion: Complex eHealth Innovation Needs a Complex Score

The main conclusion of these seven facts is that complex eHealth innovations have many ingredients: newness, availability, advanced clinical practice with proven outcomes, use and usability, the supporting environment, other context factors, and the stakeholder perspectives. As such, eHealth innovation cannot be derived from relative novelty (Fact 1) only. Additional criteria have to be met. These are partnership with advanced clinical practice (Fact 2) and use and usability in general (Fact 3). These three dimensions have to be taken into account when determining whether a change is really an eHealth innovation. These dimensions will also have to be well balanced because they may counteract each other, e.g. the newer something is the less likely its broad use. After an eHealth innovation has been identified, the context of the eHealth innovation must be investigated to explore whether there are more indicators or signs for innovation, in particular for particular process and organisational innovation, and whether there are potential correlates and predictors of eHealth innovation. These context factors (Facts 4–7) embrace first and foremost IT governance and management, which includes proper stakeholder and user involvement as well as change management. It can also consider the evolution and technical integration of the eHealth innovation.

Given this, it is evident that the measurement of eHealth innovation is complex indeed. It is, therefore, desirable to break down its complexity into dimensions of eHealth innovation and corresponding feasible instruments. To this end, the development of a composite score is proposed that comprehensively expresses the nature of eHealth innovation and that integrates the three dimensions i) eHealth adoption, ii) partnership with advanced clinical practice, and iii) use and usability of eHealth. In order to better understand the momentum and mechanisms behind eHealth innovation, the fourth dimension, iv) eHealth supporting services and means, needs to be studied.

Gauging innovation along the first three criteria will allow for statements on the degree of innovation. It will thereby transform the binary interpretation of innovation into a continuous comprehension of what innovative eHealth systems are.

Making the first three dimensions criteria for innovation departs from the understanding of a product being innovative because it has become available on the market [7]. Complex eHealth innovation cannot be bought from the shelf, but must be incorporated into an organisation and demonstrate its usefulness and usability at the customer’s site. Only then can eHealth innovation unfold its very own virtue for improving the performance of the healthcare organisation and the quality of the service.

It seems reasonable to separate the measurement of adoption, on the one hand, from advanced clinical practice, use,
and usability, on the other hand, because they mirror different stakeholder. Adoption and thus general availability can be best described by the chief information officer, who has an overview of the entire IT landscape of the organisation, and usability in conjunction with use and the clinical process and service utility can only be evaluated by health care professionals and patients. Although there is some overlap between usability and the contribution of eHealth to advanced clinical processes and services there are good arguments for keeping both concepts apart. While classical usability measurement is strongly related to a certain technology, measuring the match between eHealth and advanced care processes may apply to any type of innovation, not only product innovation.

In principle, instruments for capturing or partly capturing eHealth innovation in terms of adoption, partnership with advanced clinical care, use, and usability and eHealth innovation context factors, in particular IT governance and management do exist (e.g. [16, 21, 42–44, 59, 60, 71–73]). They need to be reappraised with regard to innovation because they were not initially built to measure innovation as such but rather IT sophistication, IT performance, IT quality, IT automation, IT adoption or IT service. More research is also needed because inconsistencies between measures can exist [74].

Given the complexity of a potential eHealth innovation score it might be difficult to comprehensively measure the degree of innovation of some eHealth development in its early phases. In these cases, some criteria cannot be actually quantified and their fulfillment would have to be postulated. Ultimately, the full prove of something being innovative can only be given post hoc.

4. Outlook

The seven facts themselves, which are presented in this paper, are not new. They are well underpinned by a large body of knowledge. However, the notions that are collected under the roof of these facts have not been explicitly discussed in the context of defining and measuring eHealth innovation before. Some of them are strongly linked to quality issues and measuring IT quality. This connection opens further discussions along the propositions “innovation versus quality” or “innovation only with quality”.

The seven facts are non-orthogonal. Indeed, they seem to correlate to a certain degree, e.g. establishment of good practice in IT management (change management) and sociocultural change. Further research is needed to show whether these interrelations can be proved empirically.

eHealth has often been understood as something inherently innovative with no particular need for clarifying its nature. The effort for defining eHealth innovation and measuring it properly seems worthwhile. There will be a time when eHealth will not be automatically associated with innovation any longer and it will be necessary to prove the innovative character of a particular development. Already today, discussions on whether some new solution in biomedical and health informatics is potentially innovative are not new. Good definitions and instruments will substantiate these discussions and may help biomedical and health informatics to prove its innovation in a systematic manner.

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