Tackling Complexity in E-Health with Actor-Network Theory

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Abstract

In a context where healthcare costs are increasing exponentially worldwide, both developed and developing countries and making e-health a priority. However, reducing the disparity in healthcare quality and delivery by way of pervasive e-health solutions remains elusive. At least in part, this is attributed to the inherent complexity that characterizes modern healthcare environments. In order to improve current understanding and tackle such complexity, we argue how research in pervasive e-health can be enhanced by using actor-network theory (ANT).

1. Introduction

E-health represents the use of digitally enabled technologies to facilitate the exchange of clinical, administrative and transactional healthcare data ubiquitously and has the potential to offer enormous value to all actors operating in healthcare environments [1]. With the information-intensive nature of healthcare, e-health can create enormous opportunities for all healthcare actors including patients, healthcare providers and other actors. Specifically, e-health can enable patients to use healthcare services conveniently and effectively as need arises, whilst also facilitating the delivery of healthcare services for providers [2].

Irrespective of recent growth, investments in e-health lag behind those in other industries [3-5]. In fact, taking advantage of e-health benefits remains both challenging and elusive [3]. At least in part, such challenges can be attributed to the intrinsic complexity of healthcare including social issues and communication patterns [6, 7], high levels of leadership and resource commitments [8], organizational structure and culture [9], ongoing institutional changes [10], anticipated and unanticipated healthcare practice changes [11], sustaining responsible levels of growth and development requirements [12], and inconsistent or even conflicting interests and agendas of constituent stakeholders [13]. In relation to this, Wilson and Holt (2001) argue that “effective clinical decision making requires a holistic approach that accepts unpredictability and builds on subtle emergent forces within the overall system.” (p. 688). It follows that developing and implementing pervasive e-health solutions is a complex social and technological undertaking [1] which stems from a range of challenges including creating a new healthcare culture, achieving compatibility with legacy systems, and tailoring pervasive e-health solutions to address complex expectations and needs of heterogeneous stakeholders that have different and even incompatible objectives and agendas. With these challenges, healthcare is a multidisciplinary phenomenon building on many disciplines such as medicine, biomedical engineering, computer science and information systems, statistics, marketing and health promotion and management [4, 14, 15].

Although contributions to e-health research are increasing, knowledge in this area remains limited [4, 14, 15]. For example, existing research has provided limited coverage of the contextual industry settings that contribute to complexity which is a limitation since these settings can improve current understanding in relation to why pervasive e-health solutions emerge and the manner in which they are shaped. In fact, pervasive e-health solutions influence and are influenced by structures of interacting and dynamic industry and broader environmental and societal factors [3, 16, 17]. It follows that e-health solutions “encapsulate[s] the structures, routines, norms, and values implicit in the rich contexts within which the artifact is embedded” (Benbasat and Zmud, 2003, p. 186).

Given its relative novelty, we conceptualize e-health as an emerging information and communication technology (ICT) innovation. There is a plethora of studies that have explored and explained factors that impact on the adoption of e-health innovations. Using the organization as a unit of analysis, these studies culminate with rational-actor decision models which argue that organizational adopters make independent rational decisions that are driven by economic and technical efficiency objectives in health settings [4, 18]. These studies, thus, present over rationalized accounts of e-health development and adoption accounts, and they tend to ignore the institutional
complexities of modern organizational environments within which e-health innovations are developed and adopted [19] [20, 21]. However, the development and diffusion of e-health is proving to be a difficult process, in part attributable to the multi-faceted interactions and negotiations that occur among heterogeneous organizations. These can shape the development and adoption of e-health innovations; the social construction of their meaning and the manner in which their properties evolve are not only affected by, but also affect users [22, 23]. E-health innovations, are, thus, underpinned by “cooperative, multi-actor research and development” (Lyytinen and King, 2006, p. 405). This can raise challenges that are not necessarily present in traditional IS, and which can, as a result, make the use of traditional IS research methods inadequate for e-health research [4, 18, 24, 25].

The objective of this paper is to improve current understanding concerning e-health complexity. We argue that e-health complexity can be tackled by using actor-network theory (ANT). With this argument, we hope to generate insight concerning the ways in which e-health research can be extended if the contextual and social dimensions that support the complex interactions occurring in modern healthcare settings are to be systematically captured [26]. We contend that such insight can be invaluable for entrepreneurs and developers of pervasive e-health solutions and also for policy-makers at both organizational and broader industry and national levels. Additionally, there are growing calls in the literature for further research in this under-developed area [26-28].

To achieve our objective, we set about to answer the research question “How can Actor Network Theory help to tackle e-health complexity?” First, we discuss healthcare complexity after which we explain ANT. Then, we discuss why ANT might be an effective approach for tackling the e-health complexity before identifying possible challenges.

2. Healthcare complexity

Healthcare systems are often described as complex adaptive systems (CAS), in that they are comprised of smaller CASs that provide support services [29]. Often, these systems are used by and rely on individuals who can act in ways that are not entirely predictable [12]. At least in part, this complexity is the reason why these systems are often considered to be “cumbersome, unwieldy, unfriendly, and opaque” (p. 110) resulting in a high incidence of preventable healthcare service failures [12].

Healthcare systems have fuzzy boundaries. Actors in these systems can often change systems or, simultaneously, be members of other systems [12, 30]. For example, typical healthcare systems are characterized by two broad categories of heterogeneous actors including patients, i.e. healthcare consumers, and service providers. The patients are the end-users of services including personal care or healthcare-related content. Providers offer services for managing specific health problems that consumers are experiencing and include clinicians, physicians, nurses, clinical nurse specialists, dietitians, health information managers, nurse managers, respiratory therapists, social works, hospital administrators, managers, and secretaries [29].

Patients and providers are connected through communication flows and service requirements and their interaction can be facilitated by pervasive e-health applications and underlying infrastructures which are typically supplied by the providers. The pervasive e-health applications and infrastructure are created and maintained by network operators, database managers, system administrators and include non-human actors such as specialized software applications, information processing algorithms and storage devices. Additionally, healthcare settings also include structures and processes such as policies and procedures that facilitate interconnections between and amongst the various actors to support healthcare provision [29].

Together, these actors attempt to facilitate the delivery of healthcare services to patients at the right time and place [1]. Additionally, government regulators and insurance organizations play important roles in creating legal and regulatory frameworks for guiding the manner in which pervasive e-health applications operate. Thus, healthcare settings are characterized by complex webs of interactions of heterogeneous actors that have different and even possibly conflicting objectives. Complexity is likely to increase even further as these organizations undergo organizational and technological changes in response to increasing pressures for greater economic efficiency, enhanced patient safety, and increasing demand for healthcare access [31].

As actors operate in healthcare settings they use their own “internalised rules” (Plsek and Greenhalgh, 2001, p. 625) which are driven by mental models, instincts, and sometimes inconsistent rules, and are not necessarily shared by or even logical to other participating actors in the system. It follows that interactions amongst actors can result in “continually emerging, novel behaviour” (Plsek and Greenhalgh, 2001, p. 626), or even unpredictability [32] which can occur when “interactions among parts of a complex system produce variable, new, and unpredictable
capabilities that are not inherent in any of the parts acting alone” (Plsek and Wilson, 2001, p. 746). For example, the multiple transfers of patients between units (e.g. radiology to operating rooms, or between institutions, and even between off-unit venues such as hallways) can increase the risk of mistakes when physician’s orders must follow the patient, particularly when bedside nurses usually receive visual cues when a physician writes such orders to a patient’s bedside chart for administering medicines. Such cues as an informal communication rule or practice may disappear particularly when using e-health systems physicians enter orders from off-site locations, thus, unobserved by nurses which can result in medication delivery failures or even in medications being administered more than once thereby putting patients in high risk situations [33].

Healthcare systems have been described as networks of networks. They are comprised of multiple networked systems which in turn embed yet other (micro-level) systems. Additionally, healthcare systems are so interconnected that the outcomes of one system can change the context for many others [12], thereby potentially creating significant information asymmetry amongst the users of these systems [34]. Consequently, each system cannot be fully understood in isolation unless other interacting systems at the macro- and micro-levels are fully considered. For example, patients’ visit patterns at a healthcare centre, in addition to their specific illness conditions are also driven by the specific centre’s locality and wider society and regulatory rules, codes of practice, and regulations [30]. Additionally, the relationships and the role of patients in their social networks including family, friends, and support groups in local community, and their impact on patient rehabilitation efforts must also be taken into consideration as these can impact on the trajectory of a medical condition [35].

Also, actor behavior in healthcare settings is not necessarily linear [34, 36]. Complex healthcare systems cannot be fully understood by simply analyzing their components. Complexity emerges as a result of the interaction between or amongst system components as well as between the system as a whole and the changing environment in which it operates [35]. As these interactions can change overtime, the healthcare system as a whole self-organizes and adapts in response [35]. For instance, using linear assumptions that are governed by textbook rules, guidelines and protocols as a basis to provide advice to diabetes patients, may result in chaotic glucose levels and potentially harmful outcomes without considering wider illness history and specific personal circumstances [36, 37]. Various fluctuations in a patient’s vital signs considered in conjunction with patients’ historic and background idiosyncrasies will affect the manner in which clinicians respond and modify treatment regimens which may across otherwise similar patients [29].

Together, these factors, can result in adaptive actor behavior which can ultimately create a fluid reality consisting of a multiplicity of different potentially incompatible realities that pervasive e-health solutions operate in and need to address simultaneously, thereby, resulting in substantial healthcare complexity [1, 24, 37-39].

3. Actor-Network Theory (ANT)

ANT constitutes a framework for investigating how technical artifacts come into being [40-43]. It addresses the role of technology in social settings and the processes by way of which it affects or is affected by social elements in a setting over time [44]. It focuses on actors and their attempts to secure their interests by forming and strengthening alliances in actor networks which, in turn, generate technical artifacts (e.g. a pervasive e-health application) [45]. As the actor networks that generate these artifacts become stabilized, the technical artifacts are said to become taken for granted or “irreversible” [46].

Actors are human or non-human entities that can make their presence individually felt by other actors [47]. ANT offers a symmetrical treatment between the technical and the social aspects of technology, in that both human and non-human actors are treated alike. That is, technical artifacts are treated as genuine actors, in that, while just merely physical, technical artifacts constitute a dynamic embodiment of human actors’ subjectivities, including their motives, intentions, interests and prejudices [48]. Using ANT can be advantageous particularly for investigating the development of complex technology such as e-health. ANT allows investigation to be focused on the nature of an actor network as a representation of complex social interactions consisting of entrepreneurial political activities and negotiations that occur in order to enroll supporting actors or allies. Successful enrollment in a network represents the alignment of the otherwise diverse interests of its actors [49, 50].

There are two pivotal concepts underpinning ANT, inscription and translation. Inscription means that actors that develop an artifact seek to inscribe their interests into it. When inscribed, interests may be manifested as specific anticipations and restrictions concerning future usage patterns of the artifact [51]. The artifact, thus, becomes a genuine actor that has the ability to impose the inscribed interest onto other actors, i.e. the users of the artifact. Therefore, the
technical aspects of artifacts, their roles and constitutions are profoundly social [44]. Translation constitutes a variety of negotiation methods whereby different actors’ interests are continually aligned to achieve a stable actor network that is dedicated to constructing a technical artifact [52, 53]. Translation comprises problematization, interessement, enrolment, and mobilization. During problematization one (or more) initiating actor(s), also known as a focal actor, defines and constructs a problem and articulates the manner in which it affects its interests [23]. The focal actor also identifies other actors whose interests are consistent with its own and attempts to establish itself as an indispensable resource for them to resolve the identified problem [54]. The aim of problematization is to frame the identified problem in a way such that different actors draw mutually compatible understandings concerning the way the problem and its solution affect their interests rather than make all interests that same [46, 54, 55].

Interessement consists of processes that attempt to “lock in” other actors as allies or supporters in the actor network. During interessement, the focal actor attempts to convince others that the interests defined during problematization are aligned with its own. Successful interessement “confirms (more or less completely) the validity of the problematization and the alliances it implies” (Callon, 1986b, pp. 209-210). During enrolment focal actors attempt to define and coordinate roles aiming to stabilize and strengthen the emerging network. It involves “multilateral negotiations, trials of strength and tricks that accompany the interessement and enable them [focal actor(s)] to succeed” (Callon, 1986b, p. 211). Successful enrolment in networks represents the alignment of the otherwise diverse interests of its actors [50].

During mobilization the focal actor employs methods for ensuring that allies operate in accordance with their agreement and do not betray its interests [54]. Although temporarily, stability may be achieved in an actor network when allies are mobilized at which point “the underlying ideas have become institutionalized and are no longer seen as controversial” (Mähring et al., 2004, p. 214).

With ANT researchers “follow the actors” and explore how these actors themselves define unfolding events in their attempts to develop technology solutions (e.g. pervasive e-health applications) to solve healthcare problems [56, 57]. When an actor network achieves stability or agreement with respect to a technical solution, network actors are said to be aligned. In the healthcare settings, this means that relevant human actors, including patients, clinicians, policy makers, and non-human actors, including diagnostic equipment and software, codes of practice, have become aligned and their network solidified. That is, the emerging pervasive e-health applications that these actor networks are attempting to generate have become taken for granted or “irreversible” [26, 46, 58, 59].

4. Using ANT to tackle e-health complexity

ANT provides a useful vehicle to capture actor involvement in the development of pervasive e-health solutions for many reasons [1]. First, by focusing on actor networks as the fundamental building blocks for developing pervasive e-health solutions, ANT looks at the relationships between actors as complex social interactions comprising entrepreneurial and political activities and negotiations [60, 61]. That is, it examines the manner in which actors form, strengthen, and maintain networks of actor alliances in relation to pervasive e-health solutions, and how their goals are locked into patterns of interactions and in processes of ongoing alignment of dynamic interests [44]. By focusing on the evolving process of their construction, as opposed to focusing on pre-defined or fixed elements, insight can be generated concerning the effectiveness of the operation of pervasive e-health solutions and the shape that they will (or will not) take in addition to drawing attention to both anticipated and unanticipated consequences of their use in healthcare settings [39, 62]. Therefore, ANT allows investigating such questions as how and why pervasive e-health solutions “come into being and how users and other actors conform, ignore, modify, or usurp the original designers’ interests” (Faraj, 2004, p. 189). In doing so, ANT can help investigate the fluidity of the healthcare reality and the underlying complex actor interactions as they unfold [23, 24, 50, 60, 63].

This is important for two reasons: i) ANT takes an “action-oriented or formative” [39] process-based qualitative approach which opens up the healthcare ‘black-box’ which is critical if the requirements of pervasive e-health solutions are to be fully understood; and, ii) there is agreement in the literature that there is a “need to recognize that different actors can play multiple roles in multiple networks at multiple time points” (Cresswell, Worth, and Sheikh, 2010, pp. 4-5). Thus, by recognizing healthcare fluidity, ANT facilitates formative assessments to studying pervasive e-health solutions while recognizing the co-existence of multiple realities in actor networks thereby challenging predictability assumptions of traditional summative outcome-oriented or causal approaches [24, 39, 64, 65].
Second, ANT offers a rich language that allows pervasive e-health researchers “not to distinguish a priori between [the] social and technical” (p. 185), thereby encouraging “a detailed description of the concrete mechanisms at work which glue the [actor] network together – without being distracted by the means, technical or non-technical, of actually achieving this” (Hanseth and Monteiro, 1997, p. 185). That is, by considering non-human actors in healthcare settings, such as e-health hardware devices or pervasive e-health software applications, ANT examines how these can affect the behavior of human actors and are affected by them. This is important because technical objects are “no longer viewed as passive “black box” containers of information, but as playing an active role that is determined by their position in the ever-changing network” (Cresswell, Worth, and Sheikh, 2010, p. 4). By providing a lexicon that blurs the boundaries between the (non-human) technical and human actors, ANT helps achieve depth and richness in capturing the true complexity of healthcare relationships, and consequently, crystallize requirements of pervasive e-health solutions [66].

Third, ANT can be particularly useful in helping direct analysis toward improving the understanding of unfolding action. This includes identifying and distinguishing the categories of participating actors and their interests, as well as crucial developments concerning pervasive e-health solutions and actions undertaken by actors based on their interests to react to and affect such developments [67, 68]. Furthermore, with ANT, multiple human actors belonging to the same organization can be collectively deemed as a single actor and their underlying stable networks can be included or excluded from analysis as necessary. According to Hanseth and Monteiro (1997), this is justified as ANT “has a scalable notion of an actor” (p. 190), meaning that it “does not distinguish between a macro- and micro-actor because opening one (macro) black-box, there is always a new actor network” (p. 190). Actors enrolled in and committed to the (micro-level) actor networks within actant organizations can be considered to be spokespersons and representative of the interests of other actors in their organizations [69].

This is consistent with ANT assumptions concerning the use of sociological levels (e.g. individual, group, organization) as units of analysis. Specifically, “ANT focuses on the identification of networks of actors, where the networks themselves are seen to become actors, as the scope of analysis widens. This affords a flexible framework that makes the “levels” in implementation research a matter of empirical discovery rather than stipulation, and that helps thereby to foster a greater realism in capturing the action that takes place.” (Ramiller, 2005, p.53). This approach enables researchers to draw together actors from both micro- and macro contexts. In doing so, ANT focuses on micro-contexts, i.e. how actors interact with one another to shape pervasive e-health solutions, and uses findings to draw conclusions about macro contexts, i.e. political and institutional environments where actors are embedded [24].

A number of studies have been found where ANT has been effectively used to research a number of issues in healthcare. For example, ANT has been employed to examine the development and adoption of electronic patient records [59, 62], the development of indoor smoke-free regulation in relation to tobacco use policy [70], development of quality improvement collaboratives in mental health care [39], development of information infrastructures in psychiatric rehabilitation services [71], and the development of genetic testing technologies [72].

5. Challenges of using ANT in e-health research

Whilst ANT is criticized for its inherent limited capability for providing empirically verifiable evidence [24], by offering a rich vocabulary, ANT can help both with explanation and interpretations of healthcare phenomena which can help refine information and requirements specification of pervasive e-health solutions [73]. In this section, we discuss critical issues concerning the valid production of ANT accounts, including the achievement of symmetry which is necessary in order to strengthen explanation and interpretation in ANT accounts [66].

5.1. The inclusion/exclusion issue

With ANT, one must closely “follow the actors” to understand how actor network negotiations influence the shape that technical artifacts will take [53, 60, 74]. In practice, snowballing can be used to identify actors in pervasive e-health solutions networks [75]. To decide “who to include and who to exclude” (McLean and Hassard, 2004, p. 499) investigative work can be directed at contextualizing a particular pervasive e-health solution as the assemblage that researchers wish to chart [76]. While following the actors, one can stop when the contextualizers (e.g. pervasive e-health solutions negotiations, interactions, alliances) stop, i.e. as references to these contextualizers or specific actors “melt from view” (Law, 1991, p. 11).
5.2. The humans/non-humans issue

All actors including social and technical actors, rely on spokespersons to speak on their behalf [77]. Spokespersons can symmetrically speak for both “people and things, but only humans can act (can be permitted to act) as spokespersons” (Pels, 1995, p. 138). Focusing on human interpretations only can provide a social bias of the technical which can adversely affect symmetry between the two [78]. In response to this, researchers can follow Callon (1986b) who argues that “no point of view is privileged and no interpretation is censored” (p. 200). Thus, researchers can follow all those involved in doing relevant work concerning pervasive e-health solutions, irrespective of how many and heterogeneous they are [60]. Heterogeneous actors can provide different perspectives which account for multiple realities. This offers triangulation whilst reducing the possibility of interpretations being locked in one mindset.

5.3. The privileging and status issue

Technical actors (e.g. pervasive e-health applications) can be conceptualized as those whose interests they represent and inscribe [50] and which are shaped as “a consequence of the relations in which they are located and performed; that is, in, by and through these relations” (McLean and Hassard, 2004, p. 507). E-health researchers can follow Callon and Latour (1992) who argue that in the process of developing pervasive e-health solutions, both the social and the technical are “analytically composite” (p. 348) and “twin results” (p. 348) of network building processes and thus, no attempts should be made to analytically favor these solutions [78]. Therefore, the emerging pervasive e-health solutions are indeed actors, but in same manner as other actors, they are susceptible to shaping and constraint [68].

5.4. The agency issue

Once implemented, pervasive e-health solutions can act autonomously. While these may facilitate some aspects of human agency they may also constrain others, in that, “[h]umans try to marshal the agency of the machines to serve their own purposes, but cannot always anticipate and control the consequences” (Rose, Jones, and Truex, 2005, p.147). When pervasive e-health solutions do not meet requirements, remedies can be identified and implemented for unanticipated consequences suggesting that these solutions have the power of agency [79, 80]. However, with ANT “agency is assumed not to be limited to individuals, objects or social determinants, but as emerging as an effect of interactions of network components” (Cresswell, Worth, and Sheikh, 2010, p.5).

Heterogeneous Engineering and the Political Issue Law (1991) argues that: “No one, no thing, no class, no gender, can have power unless a set of relations is constituted and held in place: a set of relations that distinguishes between this and that (distribution of power), and then goes on to regulate the relations between this and that … power, whatever form it may take, is recursively woven into the intricate dance that unites the social and the technical” (p. 18). On this basis, with ANT, pervasive e-health solutions are analyzed and investigated in terms of organizational processes, negotiations, power plays, and political decision making that determine sets of relations and hierarchies between and amongst heterogeneous actors in networks [81, 82]. This helps unearth “political biases that can underlie the spectrum of choice that surface for relevant actors” (Winner, 1993, p. 370).

6. Conclusion

E-health constitutes the use of digitally enabled technologies to facilitate the exchange of clinical, administrative, and transactional data ubiquitously in healthcare settings and has the potential to offer enormous value for all actors operating in healthcare including patients and healthcare providers [1, 2]. Yet, taking advantage of the benefits that pervasive e-health can provide to improve the delivery of effective quality services in healthcare remains elusive for e-health entrepreneurs. At least in part this is attributed to the complexity of modern healthcare settings where pervasive e-health applications are expected to operate [3]. In attempts to enhance current understanding concerning underlying contextual e-health complexity factors, this paper presents an argument concerning how e-health complexity can be tackled using ANT as an appropriate investigative lens. Specifically, it can help specify the requirements of pervasive e-health services that are expected to operate in fluid healthcare settings with fuzzy boundaries where causal and predictable behaviors can be elusive. This is important because ANT can help capture the multiple realities of actor networks thereby potentially enhancing pervasive e-health effectiveness. Additionally, ANT can assist in the generation of the currently absent comprehensive, multifaceted, and unified body of knowledge necessary to conduct healthcare activities in a manner addressing present inequalities through a consistent knowledge-based effort rather than, as it is presently done, through the erratic application of ever increasing funds. An existing case that serves to underscore this is the NHS
Connecting for Health (a national e-health solution for the UK) that had to be abandoned on the 31st March 2013 after costing millions of pounds. While not a guarantee of success, we believe the adoption of an ANT analysis at the onset of this project would have helped to avoid many of the problems and crisis points experienced in this project. However, before it can be effectively applied it is vital that a deeper understanding of the critical issues, barriers, facilitators and key success factors be identified. In using ANT we realize that the theory has been criticized by several scholars (Latour, 2005). However these criticisms are connected to its appropriateness as an ontology and/or epistemology. We believe that as a lens for facilitating a deeper understanding of complex operations it is most invaluable. In closing, we believe that the use of ANT generally to shed light on the complexities of various pervasive e-health solutions at both macro and micro levels is a prudent use of this theory and we call for more research in this area.

7. References

in (Editor, 'ed.' ed.): Book A Critical Analysis of Is Innovations Using Institutional Theory, Minneapolis, MN, 2005


[71] Timpka, T., Bånga, M., Delbanco, T., and Walker, J., "Information Infrastructure for Inter-Organizational