THE CHAOTIC NATURE OF HEALTHCARE INFORMATION SYSTEMS: THE NEED FOR TRANSDISCIPLINARY COLLABORATION

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Abstract

This paper demonstrates one of the challenges of the healthcare information systems development, namely the chaotic nature of healthcare systems. Although the reliable evidence demonstrating the positive effects of health information systems on safety and quality remains inconclusive (a growing body of research revealing the unintended consequences and potentially error producing effects of health information systems' implementation. Different arguments from the literature concerning the chaotic nature of healthcare, including but not limited to the nature of patients and disease have been presented. The requirements of new ways of systems design and the need for transdisciplinary dynamic teams within the requirements engineering phase as a start has been discussed. These arguments have been investigated in the context of an exploratory case addressing one of the advanced oncology centres in the US. This paper concludes that there is an important need to rethink healthcare information systems development method, which has to be in a dynamic ongoing manner for some major issues.

Keywords: Healthcare Information Systems, Chaotic Systems, Transdisciplinarity, Systems Development

1 INTRODUCTION

During the past several years multiple research efforts have been addressing the area healthcare information systems. As discussed by Paul and Ezz (2011), although the reliable and generalisable evidence demonstrating the positive effects of health information systems safety and quality remains inconclusive a growing body of research revealing the unintended consequences and potentially error producing effects of health information systems' implementation. More and more studies have shown that the theoretical intent of healthcare technologies may manifest in varied and sometimes unsafe applications that may in effect weaken care processes. This could be due to multiple factors such as safety and quality being integrated without appropriate regard for the practitioners, care processes, technology and environment with which health information systems will interact and ultimately change (Berger & Kichak, 2004; Eslami et al., 2008; Burstin, 2008).

The study of Chiasson and Davidson (2004) has been further analyzed by Paul and Ezz (2011), as they highlight that that the effective use and beneficial outcomes of IT applications in healthcare are not guaranteed. Healthcare applications are technically complex, and the software and hardware markets are considered to be less mature than the IT markets for other industries and for medical technologies. Leaders in the healthcare field recognise that in addition to technological challenges, high levels of resource commitment and leadership, changes in institutional structures (Schriger et al. 1997), planned and unplanned changes to health care practices (Massaro, 1993), and attention to social issues (Kaplan, 2001) must also be addressed if the potential benefits of IT in healthcare are to be realised. The health care industry thus poses important social challenges and intriguing research possibilities for researchers interested in the development and use information systems and technologies. For example, Teixeira et al. (2010) believe that there are hazards associated with the

introduction of ICTs in this domain, in which a great number of projects have failed because of the lack of a systematic consideration of human and other non-technology issues throughout the design or implementation process, particularly in the requirements engineering process.

The purpose of this paper is first, to investigate the argument of healthcare being chaotic and to further suggest, some of the important concerns about the development of healthcare information systems due to such nature. Some fundamental assumptions about the subject are given substance in the next two sections as follows: section 2 provides an overview about chaotic information systems; and in section 3 the characteristics of Healthcare Systems including its chaotic nature and the need for patient centric view, are presented. Section 4 discusses the implications of such chaotic nature on healthcare information systems development including the need for transdisciplinarity teams to support this matter. Section 5 presents the findings of the US oncology medical centre case under investigation. Finally, the paper ends up with some concluding remarks in section 6.

2 OVERVIEW OF CHAOTIC SYSTEMS

The issue of complex and chaotic systems and its applications on different disciplines has been addressed by multiple authors since the early nineties (George et al., 1992; William and Toshinor; 1995). As Lu et al. (2010) discuss, nonlinear dynamic systems have driven scientists to consider chaos theory and reach beyond traditional approaches which assume that systems tend to balance and stabilise and become falsely predictable. Chaos theory can be defined as 'the qualitative study of unstable aperiodic behaviour in deterministic non-linear dynamical systems' (Kellert, 1993, p.2).

As clarified by McBride (2005) and Lu et al. (2010), chaos is considered as a part of complexity theory. Thus, in order to understand the big picture of chaos, we will first highlight some major characteristics of complexity as discussed in the literature. Based on Ho (2001), they discuss that complexity by itself is a complex and relative concept which cannot easily be defined. Some attributes for a complex system have been suggested including, for instance, subsystems which are composed of a large number of elements whose interactions are dynamic, nonlinear and have a feedback loop (Ho, 2001; Baggio and Sainaghi, 2011). Supporting this idea, Baggio and Sainaghi (2011) further explain, this non-linearity causes the dynamic generation of behaviours and structures that cannot be predicted by a mere straightforward composition. These complex adaptive systems, furthermore, continually interact with the external environment, adjusting both their structure and their behaviours. During its life a complex system gives birth to several intermediate structures that appear spontaneously without any given external guidance. This self-organisation has the objective of optimising the available resources and renders the system better suited to face external or internal burdens (Pavard and Dugdale, 2000; Procaccia, 1988; Waldrop, 1992).

Investigating literature addressing chaotic system or chaos, we can see some characteristics that are inherited from complexity. For example, Lu et al. (2010), as they emphasize that chaos describes a situation where a system is dislodged from its balance and stability which is random and unpredictable for the outcomes. One of the obstacles to studying systems within the framework of complexity and chaos is that nonlinear problems are always much more difficult to study. In the nonlinear world, even a small change in X could produce a dramatic change in Y, or conversely, a dramatic change in X could produce no discernible change in Y.

To sum up, the typical features of chaos include: nonlinearity, determinism, sensitivity to initial conditions, sustained irregularity in the behaviour of the system, and long-term prediction is mostly impossible due to sensitivity to initial conditions (William and Toshinor, 1995). The tools of chaos theory can be applied towards the understanding, manipulation, and control of a variety of systems and thus there are various types of potential commercial and industrial applications based on different aspects of chaotic systems. These application types are classified into 3 categories: 1. stabilization, 2. synthesis, and 3. analysis (Lu et al., 2010). However, in this paper, we are just going to investigate the

argument of healthcare being chaotic, which might be one of reasons that add to complexity and thus failure of such systems.

3 WHAT ARE THE CHARACTERISTICS OF HEALTHCARE SYSTEMS?

In order to discuss healthcare systems characteristics, we are going first to introduce the potential changes in health definition, followed by the implications of this view on healthcare and its current non-supportive status, ending up by discussing the nature of IS in the context of chaos, as it is considered to be the underlying arm of healthcare systems.

3.1 Healthcare as a Complex Chaotic System

Before discussing the matter of healthcare, we will present the World Health Organization (WHO) popular definition of health which has not been amended since 1948, which defines health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. This definition adds to the complexity of and expands the healthcare system as new screening technologies detect abnormalities at levels that might never cause illness **(**Huber et al., 2011)**.**

The idea that healthcare is complex and dynamic has been introduced by some researchers. They have highlighted the matter that these systems are considered to be dynamic as they are systems undergoing rapid change. In dynamic systems, change, chaos, information overload and cyclical behaviours are the norm Wheatley (1992). Although seemingly 'stable' structures may appear from time to time to be transient, system behaviour is not completely planned, but *emerges*. As one scientist views it, a dynamic system is *"*a set of coherent, evolving, interactive processes which temporarily manifest in globally stable structures that have nothing to do with the equilibrium and the solidity of technological structures. Caterpillar and butterfly, for example, are two temporarily stabilized structures in the coherent evolution of one and the same system".

Further, according to Effken (2002) managing patients' health trajectories is a collective, cooperative enterprise that requires continuous communication and is subject to emerging contingencies that require ad hoc, pragmatic responses. Since patient responses to care can never be fully anticipated, treatment is never really 'routine.' Healthcare work is further characterized by distributed decision making by people with different perspectives. Other reasons for the complexity of healthcare systems that have been even discussed since the nineties involve changes in the structure, goals and values of the systems themselves Lorenzi (1997). Many healthcare systems have attempted to transform a wide range of institutions through vertical and horizontal integration into a seamless, cost-effective whole that can provide healthcare to patients from birth to death. The shift from a single focus to the enterprise level has created additional complexity (Jacobsen, 1999).

While researchers readily adopt the idea that healthcare is a complex system, complexity itself can be taken to mean a lot of different things (Dekker, 2012). As Badri et al. (2009) discuss, consumer knowledge and expectations have grown with the population's increasing wealth, resulting in strong societal pressure to adopt policies that satisfy heightened consumer expectations (Margolis et al., 2003). Despite this, Natarajan (2006) reported that the rate of healthcare errors is far higher than other industries. Consequently, there are calls for not only knowing whether things are done the right way but also whether things are being done well (Hariharan et al., 2004). Thus, the healthcare system is complex (Natarajan, 2006) and full of challenges, particularly in developing countries (Øvretveit, 2001, 2004); including: lack of standards, which are credible, agreed and authorized by organizations and professions, which can be applied flexibly in different situations. Poorly delivered services can cause many problems such as injuries, infections and even death (Zineldin, 2006).

Table 1. summerizes some complex and chaotic features of healthcare systems:

Author	**Healthcare Chaotic Features**
Wheatley (1992).	Helathcare systems are considered to be dynamic as they are systems undergoing rapid change.
Effken (2002)	Managing patients as part of helahcare systems requires continuous communication and is subject to emerging contingencies that require ad hoc, pragmatic responses and treatment is never really 'routine.'
Lorenzi (1997)	Changes in the structure, goals and values of the healthcare systems themselves
Jacobsen (1999)	Vertical and horizontal integration that can provide healthcare to patients from birth to death added to the complexity of the systems
Badri et al. (2009) based on Margolis et al.(2003)	In general consumer knowledge and expectations have grown with the population's increasing wealth, resulting in strong societal pressure to adopt policies that satisfy heightened consumer expectations.
Natarajan (2006) based on Hariharan et al. (2004)	The rate of healthcare errors is far higher than other industries.
(Natarajan, 2006)	Lack of standards, which are credible, agreed and authorized by organizations and professions, which can be applied flexibly in different situations.
(Zineldin, 2006)	Poorly delivered services can cause many problems such as injuries, infections and even death

Table 1. Healthcare as Complex Chaotic Systems

As been reported by the WHO (2008), the response of the health sector and societies to multiple emerging challenges has been slow and inadequate. This reflects both an inability to mobilize the requisite resources and institutions to transform health around the values of primary health care as well as a failure to either counter or substantially modify forces that pull the health sector in other directions, namely: a disproportionate focus on specialist hospital care; fragmentation of health systems; and the proliferation of unregulated commercial care. Ironically, these powerful trends lead health systems away from what people expect from health and health care. When the Declaration of Alma-Ata enshrined the principles of health equity, *people-centred care* and a central role for communities in health action, they were considered radical. Social research suggests, however, that these values are becoming mainstream in modernizing societies: they correspond to the way people look at health and what they expect from their health systems.

Although that health equity is supposed to be main focus, the main characteristic trends that shape conventional health systems today include:

- a disproportionate focus on specialist, tertiary care, often referred to as "hospital-centrism";
- fragmentation, as a result of the multiplication of programmes and projects (focusing on a specific disease as based on priorities); and
- the pervasive commercialization of health care in unregulated health systems.

Other characteristics of healthcare systems which add to its complexity is political dynamics. However, this evolution from formal ethical principles to generalized social expectations fundamentally alters the political dynamics around health systems change. It opens fresh opportunities for generating social and political momentum to move health systems in the directions people want them to go. It moves the debate from a purely technical discussion on the relative efficiency of various ways of "treating" health problems to include political considerations on the social goals that define the direction in which to steer health systems. Some reforms supported by the WHO aim aimed at aligning specialist-based, fragmented and commercialized health systems with rising social expectations. These reforms aim to channel society's resources towards more equity and an end to exclusion; towards health services that revolve around people's needs and expectations; and towards public policies that secure the health of communities. Across these reforms is the imperative of engaging citizens and other stakeholders: recognizing that vested interests that tend to pull health systems in different directions raises the premium on leadership and vision and on sustained learning to do better (WHO, 2008), which in turn will add to the complexity of such systems.

3.2 Patient Centricity and the Chaotic Nature of Disease

One of the possible reasons for challenges in this context is that healthcare is a unique and complex domain and Healthcare Information Systems have human safety implications and profound effects on individual patient care (Kohn et al, 2000). So why do these projects fail? One of the issues discussed by Abraham and Junglas (2011) is that the healthcare industry has recognized the importance of patient centricity, a concept that puts at center stage the patient and the associated procedural workflow. This idea theoretically moves away from the concept of a fragmented, physician-centric care delivery organization (Porter and Teisberg, 2007). However, implementing IS based on this patient-centric concept and managing the transformation is a formidable challenge organizations (Harrison and Kimani, 2009; Szydlowski and Smith, 2009; Carr et al., 2009; Day and Norris, 2007; Porter and Teisberg, 2007). In fact, IS implementations are a perturbation in any organization, whether it is a change in processes or in organizational communication and learning (Davenport, 1998). In healthcare however there are higher stakes for failure than in traditional businesses as the slightest disruption caused by the IS can have detrimental consequences (Christensen et al., 2009).

In the same context, the idea of starting to focus on healthcare quality and patient satisfaction has been recognized by several authors as presented by Al Badri et al. (2009). This included multiple efforts such as (Ygge and Arnetz, 2001; Jackson et al., 2001; Badri et al., 2005, 2008; Zineldin, 2006; Labarere et al., 2001). Investigating the patient as a target stakeholder of healthcare systems, add to the complexity of the system. Patients themselves are complex.

When discussing the patient as a target stakeholder of the healthcare system, we need to discuss the nature of disease itself. Since the early nineties, some studies such as George et al. (1992) have highlighted the need for using the chaos models in the context of diseases. As they mention, the past decade has seen the development of the mathematical field of chaos, which allows one to model and understand orderly systems that do not follow simple linear models. Clinicians have struggled to better understand and more rigorously describe the life courses of affectively ill individuals. Consequently, they have further developed a chaos-derived mathematical formula that models the varying life phases of a specific disease, namely, recurrent mood disorders.

Denis, and Letellier (2012a), further support the idea that disease is nonlinear. As they discuss, the oncologist, for example, is confronted daily by questions related to the fact that any patient presents a specific evolution for his cancer: he is challenged by very different, unexpected and often unpredictable outcomes in some of his patients. The mathematical approach used today to describe this evolution has recourse to statistics and probability laws: such an approach does not ultimately apply to one particular patient, but to a given more or less heterogeneous population. This approach therefore poorly characterizes the dynamics of this disease and does not allow to state whether a patient is cured, to predict if he will relapse and when this could occur, and in what form, nor to predict the response to treatment and, in particular, to radiation therapy. Chaos theory, not well known

by oncologists, could allow a better understanding of these issues. Developed to investigate complex systems producing behaviours that cannot be predicted due to a great sensitivity to initial conditions, chaos theory is rich of suitable concepts for a new approach of cancer dynamics. This article is three-fold: to provide a brief introduction to chaos theory, to clarify the main connecting points between chaos and carcinogenesis and to point out few promising research.

Letellier (2012b) further support this idea from the nature of tumour perspective. As they mention, although the same simple laws govern cancer outcome (cell division repeated again and again), each tumour has a different outcome before as well as after irradiation therapy. The linear-quadratic radio-sensitivity model allows an assessment of tumour sensitivity to radiotherapy. This model presents some limitations in clinical practice because it does not take into account the interactions between tumour cells and non-tumour bystander cells (such as endothelial cells, fibroblasts, immune cells. . .) that modulate radio-sensitivity and tumour growth dynamics. These interactions can lead to non-linear and complex tumour growth which appears to be random but that is not since there are not so many tumours spontaneously regressing. Consequently they propose to develop a deterministic approach for tumour growth dynamics using chaos theory.

3.3 The Chaotic Nature of Information Systems

An information system by itself is considered to be chaotic (McBride, 2005). In treating organizations and the information systems that reside in them as non-linear systems, a number of assumptions are made (Lichtenstein, 2000). Change in the system is taken as being constant. Any apparent stable state is treated as temporary. Organizations and their information systems cannot be decomposed into simple elements because the complex interactions between processes give rise to new emergent behaviour. System elements are interdependent and interactions between them are non-linear such that linear causal links cannot be made.

Most significantly, for an interpretive use of chaos theory, effects within non-linear systems are non-proportional. Small inputs can have large effects, and large inputs result in no significant change. The use of chaos theory may provide a framework for describing and interpreting the dynamic interactions involved in the determination of IS strategy, the implementation of IS and the use of IS over a period of time. Ideas such as initial conditions, strange attractors, edge of chaos and bifurcations provide support for developing a coherent and meaningful story that offers valuable insights into the interactions between information systems and organizations (McBride, 2005).

3.4 Implications on Healthcare Information Systems

As has been discussed above and based on theoretical underpinnings, on one hand, healthcare is considered to be a complex chaotic discipline, while on the other information systems automating healthcare systems, are faced by the following challenge raised by Cilliers (p. 258): ".because complex systems are open systems, we need to understand the system's complete environment before we can understand the system, and, of course, the environment is complex in itself. There is no human way of doing this. The knowledge we have of complex systems is based on the models we make of these systems, but in order to function as models and not merely as a repetition of the system they have to reduce the complexity of the system. This means that some aspects of the system are always left out of consideration. The problem is confounded by the fact that that which is left out, interacts with the rest of the system in a non-linear way and we cannot therefore predict what the effects of our reduction of the complexity will be, especially not as the system and its environment develops and transforms in time."

Chaos and complexity theories offer fresh ways to think about challenges facing healthcare, not just within organizations but also across the healthcare continuum. Many of the principles and concepts

within these new sciences make intuitive sense, but applying them will require new competencies on the part of quality of leaders and their organizations. Furthermore, additional research is needed to explore emerging applications of the new sciences within the domains of patient safety and healthcare quality. One key will be to monitor progress in other disciplines that embrace nonlinear thinking. The knowledge base of theories associated with chaos and complexity continue to expand. Over time, it is likely that mathematicians and scientists will develop new tools for unmasking the mysteries of complex systems. Healthcare quality professionals should be ready and willing to test these ideas in the healthcare arena (Benson, 2011).

4 IMPLICATIONS ON HEALTHCARE INFORMATION SYSTEMS DEVELOPMENT

Teixeira et al. (2010) believe that hazards associated with the introduction of ICTs in this domain where a great number of projects have failed due to the lack of systematic consideration of human and other non-technology issues throughout the design or implementation process, particularly in the requirements engineering process. Some studies such as Pai and Huang (2011) have taken some of the human factors that are rarely addressed such as the acceptance of computers by nurses, and organization and management support. Although that their aim is the improvement of health service, the studies are still lacking being patient centric. This is supported by Pai and Huang (2011) where they confirm that when users feel more satisfied with the service quality of the healthcare information system, their perceived usefulness and perceived ease of use will be higher. Therefore, medical centers should not only focus on these influential forces during the system introduction period, but also continuously improve their service qualities. All of these affect users' feelings about the information system. By continuously enhancing its service qualities, the system would be able to reach its potential full performance.

4.1 The Need for New Methods for Healthcare Information Systems Development Thinking

Since the early mid 90's and early 2000s some authors such Effken (2002) have discussed the need for new development methodologies in the context of e-healthcare. For example, as Effken (2002) discuss, healthcare systems are complex sociotechnical systems in which many information system innovations fail because of problems in planning or design. One of the reasons for this is that traditional analysis methods were designed for stable, relatively simple systems and single users. New analytical approaches are needed that can encompass the complexity of changing systems and multiple, interacting users. It sometimes appears that creating and implementing a healthcare information system may be more complex than putting a man on the moon.

As mentioned above, healthcare systems are complex dynamic systems and thus following this thinking, organizations are not machines, but process structures in which relationships, not objects, are primary. In machines, stability and control make sense—and computer-based information systems are very good at imposing control in a stable system through structured dialogue, checks, etc. However, when the healthcare system is under continual change, it's difficult for a designer to design a highly structured information system—and even if the design is completed, there is no guarantee that it will be appropriate for the next iteration of the system (Effken, 2002).

Traditional analysis methods are of limited use in this context because they are designed for stable systems—and today's healthcare systems are anything but stable. One of the common models for information systems comes from control theory—the simple negative feedback loop. Control theory assumes that workers' actions are determined by the goal state, the state of the system, and the control strategy used by workers. But in complex sociotechnical systems, the initial conditions cannot be known with certainty. For example, we frequently don't know the precise nature of the patient's problems. Similarly, the goal may not be clear or agreed on—and the control strategies (e.g.

treatments) to be used may be quite unclear and only emerge after observing the patient's response to trial doses of drugs. Given these challenges, some alternative approaches have been suggested through the literature such as those listed and suggested by Effken (2002). However, in this paper we will focus on the need for transdisciplinarity within the requirements engineering phase as a start.

4.2 The Importance of Transdisciplinarity to Support Requirements Engineering for Healthcare Development

As has been discussed above, although there have been huge investments and efforts for healthcare information systems, there have been several failures. One of the clear challenges that has been discussed in this paper is the chaotic nature of healthcare and information systems itself. Due to its non-linear nature, some further efforts have to be done in order to develop it in an appropriate manner.

4.2.1 The Nature of Healthcare Information Systems and the Need of Transdisciplinarity

In order to develop successful information systems including healthcare information systems we need to understand its nature. Lawrence and Després (2004) argue that the capacity of human societies to deal with environmental questions (such as health,) are insufficient even though many professionals are convinced that they have the "right answers". The incapacity to deal with the above-mentioned problems is related to their complexity, to the compartmentalisation of scientific and professional knowledge, to the sectoral division of responsibilities in contemporary society, and to the increasingly diverse nature of the societal contexts in which people live. In addition, the lack of effective collaboration between scientists, professionals and policy decision-makers has led to the "applicability gap" in sectors that deal with both the natural and human-made environment.

Healthcare systems are complex and chaotic, where some authors have highlighted the mater that traditional development methodologies fail to support as discussed in section 4.1. Thus, we suggest that to start with, during the requirement engineering phase, it is necessary to involve transdisciplanry teams to support the necessary patient centric view and manage some of the chaotic nature of healthcare challenges. Further suggested involvement of such teams during other development phases will be discussed as per case study discussion. In this section, we are going to introduce the requirements engineering phase, followed by what is meant by transdisciplinarity.

4.2.2 Overview of Requirements Engineering and Healthcare Stakeholders

This matter is supported by *Teixeira et al. (2012) as they argue that* the success of any software system depends on how well it fits the needs of its users and its environment (Nuseibeh and Easterbrook, 2000). Software requirements comprise these needs, and requirements engineering (RE) is the process by which the requirements are determined (Cheng and Atlee, 2007). A requirement is a property that a system must exhibit in order to meet the system's motivation need; and software requirements are a property which must be exhibited by software developed to solve a particular problem within one organizational context. Therefore the software requirements are a complex combination of requirements from different people at different levels of an organization and from the environment in which the system must execute (Sawyer and. Kotonya, 2001).

System requirements add requirements of other stakeholders (such as regulatory authorities) and requirements that do not have an identifiable human source and that normally result from the intersection among technical, cultural and social environments (Sawyer and. Kotonya, 2001; Abran et al., 2004). The information system (IS) is never used on its own but always as part of some broader system including hardware, people and, often, organizations (Sommerville, 2007). Successful RE involves understanding the needs of users, clients and other stakeholders, as well as understanding the context in which the software will be used (Cheng and Atlee, 2007). Thus, identifying all the users and other stakeholders who may be impacted by the system is very important and this will help to ensure

that the needs of all those involved are taken into account and, if required, the system is tested by them.

4.2.3 The Need for Transdisciplinarity Teams for Requirements Engineering

As the requirements engineering involves multiple stakeholders, and due to multidisciplinary and chotic nature of information systems, and healthcare, this area calls for transdisciplinary research, which focuses on the organization of knowledge around complex heterogeneous domains, rather than the disciplines and subjects into which knowledge seems inevitably to become organized in academic settings (Nowotny et al., 2001), 'transcending' the academic disciplinary structure. Further, it tackles complexity in science and it challenges knowledge fragmentation (e.g. Klein, 2004; Ramadier, 2004). It deals with research problems and organizations that are defined from complex and heterogeneous domains (e.g. Horlick-Jones & Sime, 2004). Beyond complexity and heterogeneity, this mode of knowledge production is also characterized by its hybrid nature, non-linearity and reflexivity, transcending any academic disciplinary structure (Balsiger, 2004). From Galliers (2004) perspective, transdisciplinarity is about joint problem solving among science, technology and society. In the 'ideal case', this problem solving process is preceded by an exercise of joint problem defining. The success of the transdisciplinary approach is based on the preparedness of all participants (all disciplines, the public, and the politicians) to work in an atmosphere of transparency, trust and openness, trying to balance personal interests with interests for the common good. This means that the transdisciplinary approach, on the other hand, requires careful preparation and a willingness to understand the language and underlying philosophies of one's colleagues (Newell & Galliers, 2000).

Zhu and Augenbroe (2006) address the issue of transdisciplinarity in the context of collaboration between project stakeholders, which is a continuous process of communication and information exchange between collaborating partners throughout the lifecycle of a project, therefore, parts of an intra-organizational information process may need to be more visible to collaborating partners. In this case, transdisciplinarity needs appear to integrate four major concepts, i.e., collaborating process segment information, sub-grouping information, organizational information and business document information, in order to complement to and augment the existing strategy that focuses mainly on the exchange of construction business documents.

In the context medical applications and healthcare Gordon et al. (2013) mention that there has been a parallel shift toward transdisciplinary research in health care settings. This innovative approach emphasizes integrative and collaborative communication to blend disciplines and perspectives. It involves professionals from various disciplines working together on a common project and utilizes a new common conceptual perspective that transcends the traditional frameworks of each separate discipline (Dankwa-Mullan et al., 2010). For example, scientists, clinicians, educators, and public health professionals work together on a complex problem that cannot be resolved by any one discipline or constituency (e.g., obesity, pain management, smoking cessation) (Abrams, 2006; Dankwa-Mullan et al., 2010). Transdisciplinary research has supported collaborative strategies to enhance the development of knowledge and evidence based practice. Relationships among patients, families, communities, and health care teams have demanded diverse perspectives that contribute to science, innovation, and quality health care (Abrams, 2006).

As Gordon et al. (2013) confirm, transdisciplinary approaches have incorporated patient-centered care into research, practice, and health care policy. The Institute of Medicine (2001) describes patient-centered care as being responsive and respectful of the individual's needs, preferences, culture, beliefs, and values. These factors guide treatment decisions and influence communication and goal setting. Treatment is not limited to providing culturally and linguistically appropriate services, but culturally sensitive communication that reflects understanding, respect, and appreciation of cultural diversity (U.S. Department of Health and Human Services, 2007). Health care professionals must determine that the patient is literate and, most importantly, has the cognitive and language ability to understand and follow a recommended treatment plan. Therefore, an important application of a transdisciplinary model is intensive, ongoing interaction among team members from different disciplines enabling an

exchange of information, knowledge, and skills in an effort to work in unison (King et al., 2009). Social and cultural determinants must be seen in the context of the individual and the community that include the patient's support system. Diversity includes all aspects of culture, as well as socioeconomic status, religion, disability or ableness, age, gender, race, and sexual orientation, which all interact in a dynamic manner (Falender & Shafranske, 2004). Cultural beliefs, social, psychological, and spiritual needs, and values influence patient and family/support system's concepts of health and illness and the meaning of visible and hidden disability (e.g., traumatic brain injury (TBI), multiple sclerosis), illness, and loss Gordon & Zaccario, 2010).

The integration of the patient's family, community, and other resources provides the foundation for culturally sensitive transdisciplinary care. in the context of transdisciplinarity work across disciplinary boundaries occurs (Cartmill, Soklaridis, & Cassidy, 2011), where each team member takes responsibility for the patient as a whole.

4.2.4 Tansdisciplinarity Models

Most of the researchers, who present guidelines for transdisciplinarity collaboration in the form of suggested frameworks of models, focus on the steps that need to be followed while collaborating in a joint problem. However, Neef (2005) presents a model for transdisciplinarity that focuses on the classification of the problem investigated as a starting point. The first recommendation is about how to focus on selected problems to come up with the challenges of complexity. There are three basic questions about issues to be addressed: (1) In which way do processes constitute a problem field and where are the needs for change? (2) What are better practices? (3) How can existing practices be transformed? One of the guidelines for identifying and structuring problems is to identify its relevant disciplines (e.g. molecular biology, ethics, economy, etc.), its problem fields (e.g. poverty, diseases, etc.), and its societal practices (e.g. business, civil society, etc.).

Depres et al. (2004) have identified a framework including the steps they went through while addressing a transdisciplinarity problem. They have also shown the key stakeholder's involvement in each phase. It is obvious that there is a coordinating team for each phase to facilitate the interaction between the multiple stakeholders including experts from different disciplines. In this context, some researchers such as Hochtel et al. (2006), have applied a theoretical concept of transdiciplinarity by presenting the successive work stages of a research project that they have conducted. It demonstrates why and how transdisciplinary methodology was applied, and the experiences gained from its use. The transdisciplinary strategy was adopted since it enables researchers to cross disciplinary borders and to deal with extra-scientific "real world problems". These steps include 1) definition of the core problem, 2) problem comprehension, 3) problem analysis, 4) treatment of the subareas, 5) integration of the subareas, which will result in cross-disciplinary results that can be implemented. This involves public participation engagement.

Lang et.al (2012), provide some guidelines for transdisciplinary research design principles, which they have implemented on sustainability, which is a complex problem by itself. These phases are somehow similar to Hochtel el et al. Phase A incorporates 1) building a collaborative research team, 2) creating joint understanding and definition of the problem to be addressed, 3) Collaboratively define the boundary/research object, research objectives as well as specific research questions, 4) Design a methodological framework for collaborative knowledge production and integration and success criteria. Phase B includes 1) Assign and support appropriate roles for practitioners and researchers, 2) Apply and adjust integrative research methods and transdisciplinary settings for knowledge generation and integration. Phase C includes 1) Realize two-dimensional integration, 2) Generate targeted products for both parties, 3) Evaluate scientific and societal impact, 4) General Design Principles (cutting across the three phases) Facilitate continuous formative evaluation, 5) Mitigate conflict constellations, and 6) Enhance capabilities for and interest in participation.

5 CASE FINDINGS

As mentioned, the aim of this research is to address some of the challenges facing healthcare information systems that could possible lead to its failure. In this paper, we are focusing on investigating the chaotic nature of healthcare, and its implications on systems development. This also includes exploring the applicability of patient centricity in healthcare information systems, as the patient and his disease(s) are from one hand part of the chotic nature of information systems, and from the other hand, s/he is one of the main stakeholders in information systems development as based on the requirements engineering thinking.

5.1 Research Method

In order to perform this investigation, the research method that has been selected is the case study research method. This is because it enables in depth investigation required for such a study. Further, the specific type of case study is exploratory. This type of case study is used to explore those situations in which the intervention being evaluated has no clear, single set of outcomes (Yin, 2003). In the context of this research a qualitative approach is more appropriate as such approach can be used to: (a) investigate little-known (b) examine in depth complex processes; (c) examine the phenomenon in its natural setting and, (d) learn from practice. In doing so, various data collection methods such as interviews and documentation were used. This study includes embedded units of analysis. Thus, separate in depth interviews have been conducted from both medical specialists as well as the IT sides. The analysis technique utilised in this research is pattern matching. The bias that is considered to be a danger in using qualitative research approach is overcome in this research by data triangulation.

5.2 Case Description and Results

The case under investigation is one of popular centers in the United States. It incorporates multiple networks of centers in different specializations one if which is its cancer center, which is nationally recognized for quality, with accreditations from the American College of Surgeons Commission on Cancer, National Accreditation Program for Breast Centers (NAPBC) and American College of Radiology for our Breast Imaging Center of Excellence. With the opening of their new Cancer Resource and Support Center (CRSC), patients at risk for cancer, the newly diagnosed patient, those in treatment and those in survivorship have the availability of a full continuum of services in an environment of patient comfort and dignity. Among the services offered are: American Cancer Society-trained cancer resource volunteers to provide educational information and guidance, new patient orientation classes, nurse navigators, financial navigator, genetic counselor, survivorship nurse practitioner, registered dietitian, integrated therapy, support groups and community forums. Patients have access to a broad array of clinical research trials in the country. Their multi-disciplinary team of cancer specialists meets weekly to coordinate the most appropriate treatment plan, which is individualized to meet the physical, mental and spiritual needs of ther patients, their families and the community.

First, there has been a consensus that the WHO (1948) definition of health discussed above as a start is challenging now, as the new screening technologies detect abnormalities at levels that might never cause illness. When asking the medical party about whom would they consider as a patient then, it has been confirmed that a patient is one who visits the center with a complaint, or someone who is doing regular check-up, or those who are under management. Clearly, each of those categories needs different types of support where specific data is required incorporating multiple processes, which adds to the complexity of healthcare. Although that the data gathered in the first visit for all categories is almost the same (management phase) but thereafter changes happen depending on the case (follow up), which means that the patient status might change from a status to another. This will require new

management methods for the patient. On one hand, once a patient has been registered, the relationship with the primary care usually doesn't end; on the other hand the relationship with specialists might end. As each patient can be possibly seeing more than one specialist especially due to the complications of the cancer therapy, data can be shared between medical stakeholders as hardcopies, where the patient consent is mandatory. This is considered as one of the challenges of integration. A patient may suffer from multiple diseases, which can be classified as primary, secondary, surgical, and diagnosis. This matter is dynamic, which adds to the complexity of the healthcare system.

Concerning the chaotic nature of healthcare, it has been confirmed that they present chaotic features. For example, systems do not manifest any fixed, repeatable patterns where nonlinearity occurs. In this case even a small change in X could produce a dramatic change in Y, or conversely, a dramatic change in X could produce no discernible change in Y. In general the response of patients to therapy is variable due to several factors. An example that has provided here, are patients who had previous side effects of radiotherapy, might reproduce dramatic reactions. Patients with genetic disorders such as (DNS fragmentation syndrome) are very sensitive to the therapy. When the patient suffers from specific multiple disease such as hypertension and diabetes, the side effects could be extreme. Some features of the complex chaotic systems may apply to healthcare systems in the case under investigation, such as the order of the variables difficult or impossible to describe in simple terms and requires complex narrative description and that healthcare is fragile and may be disrupted by small environmental changes. Further, it may sometimes happen that any patient presents a specific evolution for his cancer where he is challenged by very different, unexpected and often unpredictable outcomes.

Some other features of chaotic systems may occur but are uncommon such as the occurrence of periods of inactivity that may be punctuated by sudden change, where apparent patterns of behaviour may disappear and new patterns unexpectedly emerge. There has been an argument discussed above in the literature, concerning the matter that dynamics of cancer disease does not allow to state whether a patient is cured, to predict if he will relapse and when this could occur, and in what form, nor to predict the response to treatment and, in particular, to radiation therapy. The case results show that although some degree of prediction occurs, for a specific patient there is no guarantee that this will apply. This also varies according to the stage of the disease and type of cancer.

It has been agreed that healthcare can be described by nonlinearity, determinism, sensitivity to initial conditions, sustained irregularity in the behaviour of the system, and long-term prediction is mostly impossible due to sensitivity to initial conditions. Part of its complexity is due to the nature of the work itself, where "Managing patients' health trajectories is a collective, cooperative enterprise that requires continuous communication and is subject to emerging contingencies that require ad hoc, pragmatic responses. Since patient responses to care can never be fully anticipated, treatment is never really 'routine.' Each tumour has a different outcome after irradiation therapy. Similarly, each patient has a different response, which might be also variable in different time dimension and phases of the disease or age. Healthcare work is further characterized by distributed decision making by people from different perspectives. For example, sometimes patients do not give a good history and forget to tell something important like previous treatment they have been prescribed, which in turn can have negative effect on the treatment.

From the above results we can see that most of the chaotic features of the case under investigation are patient related, which shows the importance of patient centric development in the context of healthcare information systems. However, due to its dynamic it is a challenging step by itself. Table 2. summarizes the patient related factors that affect the chaotic nature of healthcare.

Feature	**Findings**
Patients Categories	Multiple categories of patients, where different types of support where and specific data are required incorporating multiple processes.
Dynamic nature of the patient	Patient status might change from a status to another. This will require new management methods for the patient.
Endless relationship with primary care	Once a patient has been registered, the relationship with the primary care usually doesn't end.
Legal challenges concerning patient data privacy as a barrier for shareability	The need for patient consent is mandatory is considered as one of the challenges of integration and exchanging records between stakeholders supporting the patient.
Multiple specialists per patient	As each patient can be possibly seeing more than one specialist especially due to the complications of the cancer therapy.
Multiple diseases per patient	A patient may suffer from multiple diseases, which can be classified as primary, secondary, surgical, and diagnosis. This matter is dynamic.
Response to therapy	The response of patients to therapy is variable due to several factors.
Unpredictable outcomes of therapy	Any patient may present a specific evolution for his cancer where he is challenged by very different, unexpected and often unpredictable outcomes.
The dynamics of cancer disease	- The dynamics of cancer disease does not allow to state whether a patient is cured, to predict if he will relapse and when this could occur, and in what form, nor to predict the response to treatment - Although degree of prediction occurs, for a specific patient there is no guarantee that this will apply. - This also varies according to the stage of the disease and type of cancer.
Treatment is not routine	- Patient responses to care can never be fully anticipated, treatment is never really 'routine.' - Each tumour has a different outcome after irradiation therapy. - Each patient has a different response, which might be also variable in different time dimension and phases of the disease or age.
Inaccurate patient history	Sometimes patients do not give a good history and forgot to tell something important like previous treatment they have been prescribed, which in turn can have negative effect on the treatment.

Table 2. Patient Related Chaotic Features of Healthcare

The issue of patient centricity and healthcare information systems development, which adds to the complexity of healthcare information systems multiple issues that have been referred to in the literature have been confirmed. As a starting point, it has been confirmed from the medical specialist's point of view that technology in healthcare can kill, which means that safety should be the number one priority for any technology used for processes of care. This can occur with computer assisted radiation devices, or unreliable patient records, as examples. Thus, careful attention needs to be given to the healthcare information systems development. In this context, the stakeholders for the case under

investigation, they include medical insurance companies, social workers (e.g. cognitive therapists), and healthcare providers (specialists, nurses, paramedical, etc.). These teams have not been directly engaged in the requirements engineering phase as the software as part of the IT infrastructure is based on specific vendors, and were not based on in-house development. However, apart from the automated systems, these teams collaborate on regular basis through committees as regarding the management of the cases. Other stakeholders include pubic health services and government, but are not involved in the ongoing meetings. The patients are not engaged in such collaboration meetings. However, it has been agreed that multiple issues are important to understand concerning each individual patient case. Diversity includes all aspects of culture, as well as socioeconomic status, religion, disability, age, gender, race, and sexual orientation, which all interact in a dynamic manner. The consideration of cognitive abilities, language, education, health literacy, social, psychological, and spiritual needs, as well as environmental and financial factors, provides an opportunity to view the patient in a broader context. Healthcare professionals need also to determine that the patient has the cognitive and language ability to understand and follow a recommended treatment plan. Added to that individual's needs, preferences, beliefs, and values, surrounding environment and possible health hazards are important to consider. Social and cultural determinants are seen in the content of the individual and the community that include the patient's support system.

Therefore, an important application of a transdisciplinary model is intensive, ongoing interaction among team members from different disciplines enabling an exchange of information, knowledge, and skills in an effort to work in unison. This is already implemented in the case under investigation on regular basis but not as related to the healthcare information systems development. Regular meetings for case management occur. There are different committees some of which are related to common cancer diseases. The roles of such committees are not limited to the management of the cases, but also relating the practices to the outcomes and guidelines of other committees among the US such as the National Comprehensive Cancer network (NCCN) guidelines.

Patient information obtained by the health care team members must be shared across the various disciplines that are involved in the patient's care. Sharing information facilitates team member's access to the patient's life situation, which leads to a more comprehensive plan of care. This is subject to the patients consent as per regulations in the context of the case under investigation in this paper. The exchange of these perspectives should be placed in the context of each profession, while having respect and appreciation for the unique contribution of each discipline.

Investigating the applicability of some of the steps of transdisciplinarity problem solving discussed in the literature above, it has been confirmed that this may apply to healthcare system under investigation. For example, we can classify the disciplines such as radiotherapy, problem fields such as disease and poverty, and social practices, such as civil society. However, we suggest to mimic the classification of committees that have been already developed on manual basis. Further, the collaboration needs to be ongoing, not just through the requirements engineering phase, but also during other following phases of the lifecycle. Our argument is what has been confirmed above regarding the dynamic nature of healthcare, its patient and disease. For patient, having a specific primary disease, and possibly other secondary set of disease, is not always permanent. Due to therapy other side effects may trigger other health issues. Further, at other phases, the same patient can build another primary disease. Last but not least, other issues for the same patient need to be taken into consideration such as changing the living environment or aging over time. All these factors may require different transdiciplinary teams.

6 CONCLUSIONS

This paper has investigated one of the challenges of the healthcare information systems development, namely the chaotic nature of healthcare systems. It appears from the empirical evidence that the nature of healthcare is chaotic and dynamic due to several issues, including but is not limited to the nature of disease, the patient and surrounding environment, and the need for patient centric design. It has been clear that the chaotic nature of healthcare is highly related to the

patient himself, which requires patient centric development. However, the results show that one of the barriers of implementing the patient centric view is the lack of patient engagement within the management committees, and the reliability on vendor-based software. The chaotic nature of healthcare requires ongoing transdiscilinary collaboration, during the requirements engineering phase, and the whole lifecycle. Traditional development methodologies, which assume that such an environment is static cannot support healthcare in an appropriate manner. This paper concludes that there is an important need to rethink healthcare information systems development method, which has to be in a dynamic ongoing manner because of some major issues. Thus, future research needs to focus on dynamic methods for healthcare development to overcome these challenges.

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