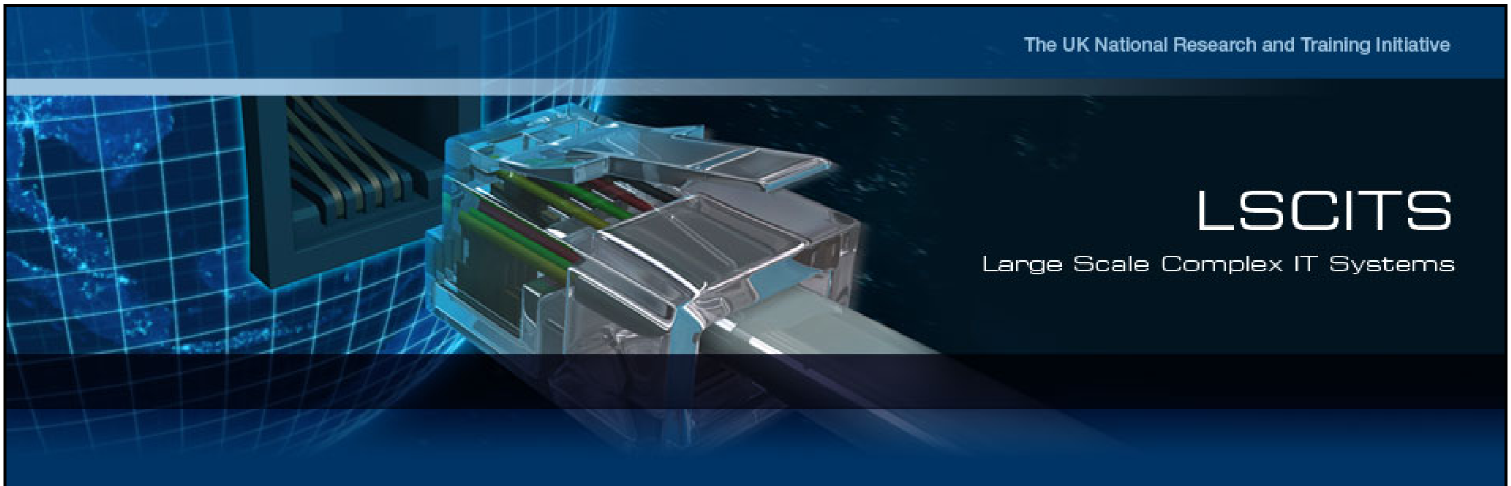

White paper: Complexity in health care

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Introduction

The way that health care is delivered has changed significantly over the last 30 years. These changes have led to new and different sorts of failures, as noted in the Institute of Medicine's influential report, *To Err is Human* (2000). This report highlighted the safety issues involved and gave rise to the patient safety movement, including the National Patient Safety Agency in the UK[1]. Their work, which is underpinned by research in human expertise, collaborative work, and high reliability organisations (Woods, et al., 2007), emphasises the needs to:

- Use a systems approach to understand how breakdowns occur, and how to support decision making in health care as it becomes increasingly complex.
- Move beyond the blame and shame cultures that have hampered the open flow of information and learning about vulnerabilities to failures in health care.
- Create partnerships across all the stakeholders in health care to accommodate differences, and make progress on an agreed overarching goal.

The importance of complexity in health care is recognised by the World Health Organisation (WHO), who mandate "Understanding systems and the impact of complexity on patient care" in their curriculum on patient safety for medical schools (World Health Organisation, 2009). This relationship between complexity and safety in health care is a focus for fields like resilience engineering (Hollnagel, et al., 2006), which regards complexity as an obstacle to safety (Woods, et al., 2007). As systems become more complex and highly coupled (Perrow, 1984), recognising failures becomes increasingly difficult (Woods, et al., 1994). This is partly because failures are the result of a combination of several factors, and can therefore be described from several different viewpoints. Working out how to recover from failures is also harder in highly coupled systems, because recovery actions can trigger multiple, possibly unanticipated, knock-on effects elsewhere in the system. High coupling also makes it more difficult for an individual (or even a group) to maintain a valid mental model of how the system works, so people become more specialised in just one part of the system.

In resilience engineering it has been suggested that the foundation for safer system operations should be based on three basic areas of research:

1. Identifying the sources of complexity. This includes noting where simple approaches break down.
2. Understanding the strategies used by individuals, teams and organisations to cope with complexity.
3. Creating better ways of helping people cope with complexity so that they can achieve success.

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[1] http://www.npsa.nhs.uk/

Different views of complexity in health care

There is a range of views on complexity in health care. At one end are those people who regard health care as a complex adaptive system, and use the term *complexity* in the sense of complexity science. This view, proposed in the *British Medical Journal* in 2001 (Fraser & Greenhalgh, 2001; Plsek & Greenhalgh, 2001; Plsek & Wilson, 2001; Wilson & Holt, 2001), claimed that a new view was needed to reflect changes in the delivery of health care since the 1970s: diagnoses and treatment are now more evidence based, and decisions are made and implemented by multidisciplinary care management teams. Plsek and Greenhalgh (2001) therefore view health care as a complex adaptive system in which:

- Boundaries are blurred (fuzzy), rather than fixed, and well-defined
- Agents' actions are based on internalised rules
- Agents and system(s) can adapt to local contingencies
- Systems are embedded within other systems and evolve over time
- Tension and paradox are inherent, and do not necessarily need to be resolved
- Interaction leads to continually emerging, new behaviours
- Non-linearity is inherent
- Unpredictability is inherent
- Patterns of behaviour are inherent
- Attractor behaviour
- Self-organisation is inherent through simple locally applied rules

This view has not received universal support, at least within the UK (e.g., see Reid, 2002). The alternative views of complexity agree with several of the attributes listed above, but they do not go as far as resorting to complexity science to find the solution. The WHO's view of complexity, for example, is based on Runciman et al.'s (2007) book, *Safety and ethics in healthcare: A guide to getting it right*, which regards health care as a complex system with emergent behaviour, many interacting components, and inherent unpredictability. The WHO view also resonates with Effken's (2002) view of health care systems as dynamic complex socio-technical systems.

Where does complexity in health care come from?

There is some agreement about the sources of complexity in health care, even though there is no single definitive list. This is partly because of the wide range of stakeholders involved in health care, many of whom will have different perspectives on the issue of complexity.

The WHO refers to broad clusters of safety process measures that are applicable to health care. If these are combined with the factors which overlap with the important generic factors that affect complexity (Hollnagel & Woods, 2005), we can produce a general list of sources of complexity in health care:

- People (patient and health care provider) factors including insufficient training and lack of expertise
- Task factors, including workflow, time pressure, job control and workload and insufficient knowledge
- Technology and tool factors, including general dependability, usability and the complexity of the interface that provides information about the current system state and the mechanisms for executing intended actions
- Team factors including communication, clarity of roles, and leadership
- Environmental factors including physical layout, lighting, and heating
- Organisational factors including organisational structure, culture and policies and procedures

Although these factors are largely applicable to most safety-critical systems, Runciman et al. (2007) believe that health care *is* different from other complex systems. In particular, they contend that health care is more heterogeneous—both in terms of the range of tasks, and the ways that they can be performed—than other domains such as nuclear power and aviation. They also point to the intrinsic vulnerability of patients (unlike aircraft passengers, for example) which makes them more susceptible to harm when things go awry: the mortality rates of some planned clinical procedures regularly exceeds 1%, for example, which is much higher than corresponding rates for standard procedures in many other domains.

How can we address complexity in health care

Existing system development methods were designed for (more or less) stable systems, with clearly defined, and largely unchanging goals. In health care, however, the goals may be vague, and the treatment[2] may only emerge as the result of trials. Furthermore, these goals can often be achieved in several ways. In neonatal intensive care, for example, experienced individual neonatologists may independently select different ventilation strategies—all of which are valid—to deal with the same case (Tan, et al., In press).

There are few, if any, examples of how complexity science has been applied to solving the problem of complexity in health care. There have, however, been several suggestions of how to deal with problems of complexity in the health care system, without using complexity science. These can be divided into three basic types.

1. *General guidelines*. Grasha (2000) proposed a set of seven design guidance principles that explicitly consider how people interact with and deal with the complexities of systems: These guidelines include consideration of critical and non-routine interactions between people as well as interactions between people and equipment.

[2] You can think of this as the control strategy for a particular patient

2. *Socio-technical approaches*:

    a. *Analysis*: Effken (2002), for example, combines Cognitive Work Analysis (Vicente, 1999) with Carper's (cited in Effken, 2002) *ways of knowing* to create an integrated analysis matrix. The matrix highlights which kinds of data need to be collected, and pinpoints the key variables that need to be analysed in each cell. The key focus in this approach is the identification of the constraints on the system (and performance), and specifying how tight (or relaxed) they should be. Kaplan et al.'s (2001) matrix-style approach to analysis works at a more detailed level, combining participants and organisational level on one dimension, with social science discipline on the other to identify questions to ask during analysis.

    b. *User modelling*: Mirel (2003) focuses on the need to ensure that the user model is correct. She proposes modelling complex work using socio-technical patterns (rather than user interface or software design patterns), which are framed using task landscapes. These landscapes capture the characteristics of complex problem solving in complex dynamic domains, such as inexactness, equifinality[3], flux and uncertainty.

    c. *Design*: Lenz and Richard (2007). emphasise the design of the processes involved, concentrating on process management and workflows, and highlighting the distinction between organisational processes and medical treatment processes. Barach and Johnson (2006) regard health care as a system of systems (although they are referring to economic systems, social systems and so on, rather than technical systems). Their solution is based around developing (clinical) microsystems, an organising construct that encompasses the appropriate human/social dynamics. The fundamental elements include the patients, clinicians and support staff, information and IT, and the care processes. These microsystems evolve over time and respond to the needs of their patients and providers as well as adapting to external pressures such as regulatory requirements. Several Microsystems simultaneously co-exist within macro organisations such as hospitals.

3. *General*. Woods, Patterson and Cook (2007) note that a one size fits all solution is unlikely to succeed. Instead they suggest things that need to be done, and things that need to be avoided in order to create systems that are more likely to be resilient, and hence be successful. These include: a detailed understanding of the work context and performance shaping factors; simplifying operations, where possible; monitoring and managing complexity as it changes over time; using

[3] The fact that there are several ways to achieve the same goal

human-centred design techniques; making automation a team player; understanding that complexity changes as the system evolves over time.

Summary

The importance of complexity in health care systems is widely recognised and acknowledged. The issue of complexity has mostly been addressed from a patient safety point of view. Although some see health care as different from other complex systems, such as aviation and nuclear power, there are several sources of complexity that are common across all of these domains.

The various solutions proposed for dealing with complexity in health care tend to focus on a small number of aspects, or just one phase of systems development. The main exception is the general approach adopted within resilience engineering, where lessons are learnt and applied from other domains as well as health care.

The fact that several of the proposed solutions are based on socio-technical approaches, and that resilience engineering has a contribution to make are important from the LSCITS project point of view. The LSCITS project's expertise in socio-technical systems engineering (St Andrews) and complexity in organisations (Leeds) will enable us to offer further insights into complexity in health care, and how to deal with it, at least within the UK. As yet, nobody has come up with a definitive answer for dealing with complexity in health care, so it remains very much an open area of research.

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LSCITS is the UK's national research and training initiative in the science and engineering of Large-Scale Complex IT Systems.

Leading British academics and industrial practitioners established this national strategic coordinated research and training initiative with a headline funding of over £15m. Research is being undertaken at a consortium of universities including Bristol, Leeds, Oxford, St Andrews and York.

The motivation for the LSCITS Initiative is the on-going growth in the size and complexity of information technology (IT) systems. Our ability to develop, maintain and manage such systems is falling behind the growth in their complexity. There is a high risk that we will find ourselves reliant on IT systems that we don't fully understand and that we cannot effectively manage.

We are addressing this risk at different levels of abstraction through the research of: Complexity in Organisations; Socio-Technical Systems Engineering; High Integrity Software Engineering; Predictable Software Systems; and Novel Computational Approaches.

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