RESEARCH METHODOLOGY: EMPIRICAL RESEARCH – METHODOLOGY

Application of simplified Complexity Theory concepts for healthcare social systems to explain the implementation of evidence into practice

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Abstract

Aim. To examine the application of core concepts from Complexity Theory to explain the
findings from a process evaluation undertaken in a trial evaluating implementation strategies
for recommendations about reducing surgical fasting times.

Background. The proliferation of evidence-based guidance requires a greater focus on its
implementation. Theory is required to explain the complex processes across the multiple
healthcare organizational levels. This social healthcare context involves the interaction
between professionals, patients and the organizational systems in care delivery. Complexity
Theory may provide an explanatory framework to explain the complexities inherent in
implementation in social healthcare contexts.

Design. A secondary thematic analysis of qualitative process evaluation data informed
by Complexity Theory.

Method. Seminal texts applying Complexity Theory to the social context were annotated,
key concepts extracted and core Complexity Theory concepts identified. These core concepts
were applied as a theoretical lens to provide an explanation of themes from a process
evaluation of a trial evaluating the implementation of strategies to reduce surgical fasting
times. Sampled substantive texts provided a representative spread of theoretical development
and application of Complexity Theory from late 1990's–2013 in social science, healthcare,
management and philosophy.

Findings. Five Complexity Theory core concepts extracted were 'self-organization',
'interaction', 'emergence', 'system history' and 'temporality'. Application of these
concepts suggests routine surgical fasting practice is habituated in the social healthcare
system and therefore it cannot easily be reversed. A reduction to fasting times requires
an incentivised new approach to emerge in the surgical system's priority of completing
the operating list.

Conclusion. The application of Complexity Theory provides a useful explanation for
resistance to change fasting practice. Its utility in implementation research warrants
further attention and evaluation.

Keywords: Complexity Theory, controlled trial, fasting, guideline, health and
social system, implementation, nursing, process evaluation

Why is this research, or review needed?

- Implementation of evidence-based recommendations continues to be 'patchy'.
- The implementation context for evidence-based practice requires greater attention to the theorizing of interactions between individual professionals in the organization of care.
- Patterns of professional behaviour influence the successful implementation of practice change.

What are the key findings?

- The application of Complexity Theory concepts specifically applied to the social healthcare context provides an explanatory theoretical lens to address complex phenomena such as the organization of healthcare.
- Fasting practice is habitual and embedded in the management of surgical operating lists and therefore cannot be simply 'dismantled' to accommodate individualized fasting times before induction of anaesthesia.

How should the findings be used to influence policy?

- Resistance to practice change could benefit from the application of this theoretical lens.

Introduction

In 1984, a diverse interdisciplinary group of researchers spanning physical, biological and social sciences were brought together to study complex systems based on non-linear thinking from the cellular level to human society (Gell-Mann 1994). Since early 2000, the language of Complexity Theory has progressively entered the lexicon of healthcare sciences to understand better the complexities of the healthcare context, interventions and their implementation (Fraser & Greenhalgh 2001, Plsek & Greenhalgh 2001, Moore *et al.* 2014). Complexity Theory specifically addresses the phenomenon of 'complexity' and explains the behaviour of complex systems (Johnson 2011). In this paper, we examine the core concepts of Complexity Theory applicable to the *social* healthcare context to provide a structured framework for the application of this theory. Indications of the explanatory potential of these core concepts are demonstrated by applying them to the process evaluation findings from a cluster-randomized implementation trial. This trial evaluated three implementation strategies to implement

improvements to fasting times prior to routine surgery (Rycroft-Malone *et al.* 2012, 2013).

Background

Implementation and context

Implementation research is the study of methods to promote the uptake of research findings into routine healthcare in clinical, organizational or policy contexts (http://www.implementationscience.com/about (accessed 05 December 2014). Implementation research also involves understanding the context of implementation including the processes that influence and inhibit implementation of evidence (Eccles *et al.* 2009). The social healthcare context for the implementation of evidence can be described as involving several layers, including individuals (multiple healthcare professionals, non-clinical staff, patients) and organizations (hospital infrastructure, technology, computerized information systems, delivery of treatments to patients, culture and working practices). Our understanding of implementation in context has been '... hindered by the lack of a robust theoretical base for understanding healthcare provider and organizational behaviour' (Grimshaw & Eccles 2004, p,. S50). As part of an implementation research agenda Eccles *et al.* (2009) proposed the need for the application of theory to explain this multi-layered context and the interplay between professionals and patients in care delivery.

There are various theories and conceptual models that can help us understand better individual behaviour and contextual factors (e.g. Michie & West 2004, May 2006, May *et al.* 2007, Eccles *et al.* 2009). Specifically, Complexity Theory explains the multi-layered reality of health care, that is, the relationship between macro-structures (organizational) and micro-level behaviour (individual) of the system (Kernick 2004). It seeks to explain the dynamic co-existence of the multiple interactions, processes and outcomes and accounts for the unexpected consequences and events that occur over time (Rycroft-Malone 2007).

Complexity Theory

Complexity Science is an emerging discipline crossing all scientific endeavours from natural to social and health sciences (Meyers 2009). It has emerged to balance 'Reductionism', the dominant scientific approach and to address complex behaviour that arises from the interaction between large collections of simpler components (Mitchell 2009). Arising from this view of the world, Complexity Theory explains the behaviour of the whole (system) rather than its constituent parts, defined as 'the study of

the phenomena which emerge from a collection of interacting objects' (Johnson 2011, section 1.1). Complex systems are networks of individuals (e.g. people) exchanging information. These systems are incentivised to exchange this information by the shortest route (Johnson 2011). At a social level in the health system, maintaining patient care requires the optimal transfer of information between people.

A key characteristic of complex systems is self-organization. Complex systems organize from within, responding and adapting collectively to stimuli external to the system boundary (Johnson 2011). This perpetual interaction of individuals, for example, leads to greater system complexity and emergent phenomena (Johnson 2011), often cited as 'greater than the sum of the parts'. The term complex adaptive system (CAS) (Gell-Mann 1994) is often used as a metaphor to counter the more mechanistic description about organizations as machines (Wilson & Holt 2001, Plsek 2003). Although, Complexity Theory is not yet a fully developed unified theory (Johnson 2011) due to its interdisciplinary nature in both natural and social sciences, it does share some concepts across these disciplines including self-organization, emergence and adaptation leading to increased system complexity (Mitchell 2009).

There has been an increasing interest in applying Complexity Theory to health care (Sweeny & Griffiths 2002, Holt 2004, Kernick 2004), which was energized by a set of papers published in 2001 (Fraser & Greenhalgh 2001, Plsek & Greenhalgh 2001, Plsek & Wilson 2001) followed by the publication of two books on the application of complexity in health care (Sweeny & Griffiths 2002, Kernick 2004). Recent Medical Research Council (UK), (2014) guidance on process evaluation of complex interventions suggests Complexity Theory has potential, such that process data capture of feedback loops can allow investigation of complex causal pathways. However, examples are required (Moore *et al.* 2014). This paper begins to fill a gap by providing an exemplar to illustrate the potential of Complexity Theory to explain the complexity of the social context in healthcare systems.

The study

Aim

To examine the application of core concepts from Complexity Theory to explain findings from a process evaluation undertaken in a trial evaluating implementation strategies for recommendations about reducing surgical fasting times.

Design

A secondary thematic analysis of qualitative process evaluation data informed by Complexity Theory.

Methods

Extraction of core Complexity Theory concepts
A purposive selection of Complexity Theory texts was examined to derive some common meanings about social theorists' interpretations of Complexity Theory. Sampled substantive texts provided a representative spread of theoretical development and application of Complexity Theory from late 1990s to 2013 in social science, health care, management and philosophy. This was a key period of development in these scientific fields. Selected works were Cilliers (1998) (philosophy), Bryne (1998, 2013) (social science), Kernick (2004) (organizational – health care specific), Stacey (2003) (organizational – strategic management), Sawyer (2005) (social theory) and Castellani and Hafferty (2010) (sociology and complexity science). Key contributors to the development of Complexity Theory have been identified (Castellani's map (http://www.art-sciencefactory.com/complexity-map_feb09.html, (accessed 08 December 2013) and additional works identified for this study, Stacey, Sawyer, Byrne and Kernick, are included. An adaptation of Castellani's map is available in Supplementary Information File S1 – with permission from the original author.

The broader Complexity Theory literature proposes that the key concepts of self-organization of interacting agents, adaptation, emergent structures (Gell-Mann 1994, Kaufman 1995, Holland 1998) and the irreversibility of time (Priogogine 1997) are central to this theory. These provided an initial framework with which to synthesize the purposively selected texts, which involved annotation, extraction and theming to develop the framework of core concepts.

Applying the core concept framework
The findings of a cluster-randomized controlled trial to evaluate implementation strategies to address the practice of prolonged fasts before routine surgery included an embedded process evaluation described in full elsewhere (Rycroft-Malone *et al.* 2012, 2013). A key evidence-based recommendation specifies nil by mouth before induction of anaesthesia should be at 2 hours (RCN/RCoA 2005). The trial primary outcome was duration of fast before induction of anaesthesia. The conceptual framework Promoting Action on Research Implementation in Health Services (PARIHS) (Rycroft-Malone *et al.* 2002, Rycroft-Malone 2004) underpinned the study. This framework represents

successful implementation as a function of the nature of the evidence being implemented (credible, robust, consensus about it), the context of implementation (receptive and conducive) and the process by which it is appropriately facilitated.

The process evaluation included a total of 49 semi-structured audio recorded interviews with staff, 70 interviews with patients and five focus groups ($n = 32$) with staff undertaken pre- and postintervention. Thematic content analysis informed by the study's theoretical framework was conducted on the data. Further information on the analysis and rigour of this data is available elsewhere (Rycroft-Malone *et al.* 2012, 2013).

The process evaluation findings, in brief, suggest that while the evidence underpinning the guideline recommendations was strong and thought to be credible by participants, cautious behaviour was observed among some anaesthetists, nurses and patients. The organizational priority was for staff and surgical departments to manage the smooth running of the operation lists to maximize the numbers of operations to help meet waiting list targets, rather than to 'individualize' fasting times as recommended. The trial data indicated that average fasting times for Nil by Mouth (NBM) were still prolonged (>9 hours), in comparison to the recommended 2 hours at study cessation (Rycroft-Malone *et al.* 2012).

For the purposes of applying the Complexity Theory core concepts framework in this study, the findings from the process evaluation were categorized into limiting factors, communication and history (Table 1). Process evaluation findings grouped by these three categories were then analysed using the Complexity Theory core concepts framework.

Rigour
The first author undertook the extraction and summarizing of theoretical roots and development, core concepts and individual perspectives. (Second and fourth author) contributed to the development and refinement of the concepts. (Third author) checked the application of these concepts to the process evaluation findings. (First, second and third authors) were involved in the original study.

Ethical considerations
The original study was authorized by a NHS research ethics committee, which included permission to undertake secondary analysis. For the purposes of this analysis, permission was granted from a University ethics committee. Trial registration number ISRCTN18046709.

Findings

Summary of purposively sampled texts

Each text provides a distinct theoretical perspective (Table 2). Cilliers' (1998) philosophical account views complex system function as distributed along a series of connected systems in both the natural and social contexts. Bryne's (1998, 2013) complex realism perspective focuses on multiple and contingent causation in open yet bounded systems and complexity is characterized by emergence. The temporal nature of ongoing communications between individuals is the basis for social systems for Stacey's (2003) complex responsive processes. The notion of the complex adaptive system is used metaphorically to explain a spectrum of organizational thinking where 'a manager can stand outside the system and control it' to one where the 'system cannot be engineered from outside' (Kernick 2004, p. 40). Sawyer (2005) addresses a key sociological question, 'How do social facts have causal powers independent of individual agency?' (Sawyer 2005, p. 113). He presents his Emergence paradigm, specifying the 'Study of social emergence requires a simultaneous focus on three levels of analysis: individuals, their interactional dynamics and the socially emergent macro-properties of the group' (Sawyer 2005, p. 191). Castellani and Hafferty (2010) map the areas of development in Complexity Science and the complementary developments in sociology.

Although each work makes a unique contribution to this field, the purpose here has been to develop a more general explanatory framework based on core concepts for the social healthcare context. By integrating these authors perspectives, we can describe micro social phenomenon (interactions between people and processes) that collectively emerge through 'successive symbolic interactions' among autonomous individuals (meanings attributed by people) to form macro-social structures (within which fasting practice evolves) (Sawyer 2005, Castellani & Hafferty 2010). This self–organizing process operates through language expressed between people (Cilliers 1998) and is described as the 'constructive nature of conversation' that manifests as a continuous process of responses between people communicating (e.g. evolving fasting practice) over time (Stacey 2003). People (such as healthcare professionals) are defined by their relationships, (Castellani & Hafferty 2010) asymmetrically organizing over time and affected by power relations, competition, contingency, context (human and non-human) and time (Stacey 2003) in a constantly active state with traces of previous activity (historical

Table 1 Refinement of original process evaluation findings for theory application.

Study key findings extracted from the process evaluation (Rycroft-Malone et al. 2010)	Summary of key points	Overarching topic area for theory application
Limiting factors identified were: • The UK National Health Service (NHS) Hospital capacity at senior and local level to conduct the trial and the capacity of individual members of NHS staff identified to collect data. • Resources available for practice change e.g. staff time, workloads, support structures. • Level of priority and importance given to the guideline recommendations. Tweaking fasting times was not a surgical department priority. • The final outcome of a significant decrease in mean fasting duration at six surgical departments plus one with a significant increase in mean fasting time and the additional variability in other surgical departments with non-signifi cant results suggested a multi-factorial nature to the implementation of the fasting guideline. • The size and scale of the implementation task could be a factor, the weight of the operation to manage surgical operations in the light of 18-week targets applied pressure on theatres to maximize efficiency. • The variable capacity, commitment and interpretation of interventions at local implementation level compromised the implementation fidelity of the strategies across surgical departments. • The limits of the study interventions prescribed (guideline strategies) to facili tate guideline implementation. However, the level of 'activity' observed sug gested the importance of 'doing something' to change practice that was locally relevant indicating adaptation and innovation. • Practice was observed embedded into most surgical departments' policy but not actually into practice. • Prescriptive interventions did not function well, hence intervention fidelity was compromised • Degree of motivation/push in the system	Factors hindering evaluation and implementation of guideline recommendations were based on the individual surgical department's capacity to conduct the trial and support the intervention implementation strategies. The limited resources available, lack of priority given and the motivation and push illustrated this in the system. Prescriptive top down interventions were limited in the face of local adaptations and innovation activities. Fasting as a context specific embedded practice illustrated by variability across sites suggested attention to multiple factors was required.	The impact of system factors to limit (inhibit) evaluation and implementation of the proposed guideline recommendations

Table 1 (*Continued*).

Study key findings extracted from the process evaluation (Rycroft-Malone et al. 2010)	Summary of key points	Overarching topic area for theory application
Communication as a factor was identified by: The process of changing fasting practice required the co-operation and communicative feedback looping of nurses (pre-admission, ward, theatre, recovery), doctors (surgeons and anaesthetists), managers and patients. Central to this involved the management of the operating list. Fasting practice could not be separated from this process. • The guideline had provided strong credible evidence for shortening current fasting practice. Nurses and anaesthetists had overall accepted the evidence base of the guideline. • Some anaesthetists showed conservative and risk aversive attitudes with the priority given to managing the operation lists. • Influential mediators of practice change observed were inter-professional issues (e.g. tense communications) and a lack of clarity for the authority and responsibility for local fasting decisions (e.g. when operating lists changed). • Rule based and rigidity of structures e.g. levels of hierarchy, formal rules and procedures, committee structures to agree policies etc. Levels of authority, therefore a lack of enabling structures for practice change facilitation. • Individual belief systems, emotional responses (anger and anxiety), power struggles around whose responsibility and authority for fasting practice change. • Poor communication between healthcare professionals at the local level and between departments was identified as a barrier to practice change. History as a factor was identified by: • The importance of history in practice change • Although patients are suffering discomfort, many would actually rather be cautious and starve longer although most did not clearly understand why they fasted. It has historically become understood patients fast before operations and the practice is a cornerstone of surgical care. • Reluctance, resistance and caution in response to a push for practice change were observed of many healthcare professional staff, irrespective of the acceptance for the evidence. • The individual starting point of each NHS Trust within fasting practice was variable as identified by the baseline mean fasting times. • Impacts on aspects of practice and service delivery that did not translate into changes to the primary outcome mean duration of fasting in the trial time frame; however, change had begun to be negotiated. • The ability of individuals to change the parameters of an entrenched practice with a long history.	Strong credible evidence accepted by key professionals was, however, inhibited by risk averse attitudes to protect the 'operation list management system'. Authority and responsibility for policy development and management of the patient's fast was not clear (at times antagonistic) and was further hindered by rigid procedures. These set the scene for a restricted level of communication required to facilitate practice change. Fasting is the cornerstone of surgical practice with a long history and is so well established that patients fully expect to fast although many do not clearly understand why. Professionals are resistant to change a well-established practice. Changes observed through the process evaluation did not impact on the primary outcome mean duration of fast, indicating the necessity for 'time' to change entrenched practice.	The impact of communication and interaction between individuals, teams, departments and professions on the evaluation and implementation of the proposed guideline recommendations The impact of the longevity of fasting practice in the face of accepted credible evidence to change the practice

Table 2 Extracted concepts.

Author (year) Research Field and text focus	Theoretical basis and summary of author perspectives	Core concepts extracted	Summarized concepts	Interpretation of core concepts consistent with broader Complexity Theory
Cilliers (1998) PHILOSOPHY Connectionist & distributive model of complexity	Cilliers (1998) takes a poststructural position using the thinking of key philosophers Derrida and Lyotard to develop the case for distributed connected (connectionism) systems in the natural and social spheres. He uses neural networks (Artificial intelligence, brain function) and the development of language to illustrate his point.	Society is a system and can be described as a complex system utilizing characteristics of other complex systems: 1. A large number of elements (individuals). 2. Elements interact dynamically (exchange information). 3. Interaction rich (individuals interact in a 'vast array of different capacities'. 4. Interactions are non-linear, that is asymmetrical and resource competitive. 5. Short range of interactions, that is local (Society forms larger assemblages of individuals to perform specific functions, which connect) 6. Feedback loops in the interconnections (Information is continually transformed and is context and timeframe contingent) 7. Open systems (e.g. human systems interact with biological systems). 8. Far from equilibrium, (Society exists as a process and is not static). 9. Sensitivity to initial conditions (System history is about traces of origin overtime rather than providing 'true meaning of present conditions'. 10. Individual system elements lack knowledge of the whole system (Society is emergent and no individual controls or has the complete picture, although individual humans will have more control than others (power).	Society as a complex system, defined as: • Interacting elements continually transforming and feeding back. • Interaction is local. • An open system. • History of the system is relevant to status. • Emergent and no one individual controls society. • Formation of larger emergent structures.	Interaction, feedback, continual transformation Open systems fluctuating System history No centralized control Emergence into larger social structures

Table 2 (*Continued*).

Author (year) Research Field and text focus	Theoretical basis and summary of author perspectives	Core concepts extracted	Summarized concepts	Interpretation of core concepts consistent with broader Complexity Theory
Bryne (1998) SOCIAL SCIENCE Complex Realism	Bryne (1998) takes a scientific realist – critical realism (Roy Bhasker's work) approach adopting Chaos Theory and non-linear relations to address multiple and contingent causation, more recently expressed as complex realism (Byrne 2011). He illustrates this with case studies of education and urban governance and health (Bryne 1998). Byrne & Callaghan (2013) consolidates his approach to the application of Complexity Theory to Social Science and describes the application of the complexity frame of reference to the social world. Social complexity needs to engage with social theory and that any account must address human social agency and the structures that are shaped by their actions.	Rejects analytic strategies in which the whole is reduced to the sum of its parts as oppose to having emergent properties. The argument for identifying complex causality is that with a complex system you will have a range of outcomes (alternatives). However, Bryne argues that they are limited by the determinism of Chaos theory. Byrne refers to a Chaos/complexity framework to understand micro/macro inter-relationships, which in evolutionary terms is concerned with emergent order. From a *complex realist* perspective of the iterative relationship of the social world as shaped and re-shaped in ways that are not always intended and social complexity cannot be reduced to simple rules, as in some physical complex systems). Additionally, these processes are historical and are not time reversible. The social world needs to take account of the historical and ongoing present of purposeful human interaction (individual and collective agency) that results in intended and unintended consequences in a constant evolution. Complex social systems can be classified at a given point in time and causal accounts established retroductively. This takes account of social systems as assemblages.	• The whole is more than the sum of its parts and cannot be reduced to those parts. • Human intention does not necessarily result as intended. • The social world is emergent from micro to macro inter-relationships. • Social processes can not be reversed. • Social systems based on human agency are not based on simple rules. • Social structures have causal powers. • Human interaction evolves continually into emergent complex social system structures. • These structures can have causal powers on the human agents.	The social system cannot be disassembled into its parts. Social structures are emergent from ongoing interaction human. There is a continual cause and effect of human agency interaction on the social structures and the social structure has causal power on human agency. Social processes are historical and cannot be reversed.

Table 2 (*Continued*).

Author (year) Research Field and text focus	Theoretical basis and summary of author perspectives	Core concepts extracted	Summarized concepts	Interpretation of core concepts consistent with broader Complexity Theory
Stacey (2003) STRATEGIC MANAGEMENT Complex Responsive Processes	Stacey takes an historical journey through organizational theories: Systems thinking, Open systems, Second-order systems, autopoiesis Strategic choice and management, Learning organizations and psycho-analytic approaches (Group Analysis) to process thinking. Stacey proposes a theory focusing on the self-organizing and constructive nature of conversation and power relations in organizations. This takes a temporal view of change processes in organizations. People in organizations are conversing in relationships in the present in an ongoing continuous way from which strategy and potential for transformation emerges as they continually construct their future.	The concept described is '*complex responsive process*' referring to the interaction of conversation between human agents in an organization. This is understood to be temporally located, in other words a continual process ever evolving and fluid without a boundary or a clearly defined whole with an inside and an outside. An organization is a process. Complex responsive processes constitute a theory of human psychology through which people relate to each other. Interaction and human nature are the same phenomena rather than separate levels of analysis of individual and group. Organizational strategies are the evolving patterns of collective and individual identities.	• Conversation is the interacting phenomenon that organizes human agents in a continually evolving process • Boundaries are not clearly defined	Interaction through communication in a continual temporal evolution.

Table 2 (*Continued*).

Author (year) Research Field and text focus	Theoretical basis and summary of author perspectives	Core concepts extracted	Summarized concepts	Interpretation of core concepts consistent with broader Complexity Theory
Kernick (2004) HEALTHCARE ORGANIZATION (Change management) Complex Adaptive Systems as a metaphor	Kernick links social theories (Weber Taylorism, Fordism) and Systems theory to Chaos theory and organizational Soft Systems Thinking (Learning Organizations). The Complex Adaptive System (CAS) is a concept used to describe a system that acquires information from its environment creating a schema from which it acts upon the external environment. This internal schema is constantly re-modelled and hence the system adapts (Gell-Mann 1994). It is used as a metaphor to understand the function of health organizations as a network of co-evolving elements inter-dependently connected resulting in changes to all elements from changes to one.	Kernick applies the Complex Adaptive System as a metaphor to health organizations to challenge common assumptions in organizational theory that organizations function in linear, reductionist, deterministic ways allowing for political and managerial control. Modern science has been limited in its ability to predict and control human organizational behaviour and that a model of a network of co-evolving elements inter-dependently connected resulting in changes to all elements from changes to one. Applies characteristics of complex adaptive systems: key features are emergence and self-organization. A CAS adapts to its environment with the least amount of effort and driven by both competition and co-operation among system elements. The focus is shifted from outcomes to process, the importance of history and the limits to predictability.	Health organizations behave as if they are complex adaptive systems and comprise: • Co-evolving inter-dependent connected elements. • Systems that emerge from the self-organizing interaction of a large number of elements co-operating and competing and is • Historically contingent, with limited pre dictability.	Health systems evolve in a self-organizing interaction of co-operation and competition between agents connected within the system. The system adapts to influences within and beyond its boundary. These agents are constrained by their history and predictability is limited.

Table 2 (*Continued*).

Author (year) Research Field and text focus	Theoretical basis and summary of author perspectives	Core concepts extracted	Summarized concepts	Interpretation of core concepts consistent with broader Complexity Theory
Sawyer (2005) SOCIAL THEORY Social Emergence	Sawyer uses a re-interpretation of Durkheim's work to address a key sociological question, 'How do social facts have causal powers independent of individual agency?' (Sawyer 2005, page 113). Social science splits between those that study macro-level social systems e.g. societies and the micro-level social dynamics of individuals. Sawyer takes the principle of emergence to explain the development of macro-social phenomena from micro social phenomena. Human societies are unique complex systems because of the complex properties of human language and the 'sophistication of human symbolic communication'.	Sawyer sees the role symbolic communication plays in micro-macro relations as under theorized. This leads to his Emergence paradigm that describes the steps that encompasses Social Theory as an evolution. This refers to an individual level (A) of intention, agency, personality, cognitive processes through interaction level e.g. discourse patterns at level (B), ephemeral emergent at level (C) e.g. assignments of context, participation structure, stable emergent at level (D) e.g. shared social practices and finally (E) social structure e.g. procedures, laws, architecture, communication and transport networks. These emergent levels have autonomous causal powers. These levels also result in downward causation from the emergent levels E to A and constrain or enable individuals. In social systems individuals are aware of the social products that emerge from their encounters. Social life cannot be fully explained by the actions or mental states of individuals.	• Social relations and structures are a process of human interaction and emergence of social structures. • Emergent social products can constrain or enable individuals. • Emergent social products are autonomous. • Social life is not explained by the individuals within it.	Interaction results in emergent structures that have causal influence on the individuals that collectively created the structure. The emergent social structures have an autonomy that is separate from the individual constituents.
Castellani and Hafferty (2010) SOCIOLOGY Sociology and complexity	Sociological work has become increasingly complex with the transformation of society through technology and information systems, the globalization of economics, politics. Society represents a complex network. Tools from Complexity Science are used to model complex social systems. A 'Social Complexity Theory' is a conceptual framework providing a theoretical filing system and associated vocabulary. Complexity science adds to the basic concept of social practice. A social system's multiple forms of expression emerge out of the collective behaviour of micro-level interactions.	Castellani and Hafferty describe a critical sociological concept of social practice that is, 'any pattern of social organization that emerges out of and allows for, the intersection of symbolic interaction and social agency'. Social practice (interaction, dynamics, social agents, communication, social knowing) is both cause and consequence. Social practice is an emergent phenomenon and it defines, constrains, limits, controls, regulates, facilitates, creates and makes possible the intersection of symbolic interaction and social agency. A social complexity theory contains a 'filing system': 1. Field of relations: 2. Web of subsystems 3. Network of attracting clusters. 4. Environment 5. System dynamics A methodology: Assemblage (a case based, system-clustering algorithm for modelling social systems).	Social organization arises from social practice, which feeds back in a loop as cause and consequence.	Interaction within social relations (practice) is emergent from social interactions facilitating, limiting and regulating social practices.

system information and behaviour) remaining (Cilliers 1998). Complex social systems (such as that within which fasting practice operates) are irreducible to their initial states (Bryne 1998, 2013) and are constantly transforming (Stacey 2003, Kernick 2004).

Extraction of complexity theory concepts

The core Complexity Theory concepts extracted from these works were: self-organization; interaction; emergence; system history; and temporality (an elaboration of each concept is provided in Table 3).

The phenomena 'complexity' is a key characteristic of the world we live in and of the multiple complex systems that cohabit our world; such as the health system within which fasting practice is implemented (Simon 2008). Our perspective is that the implementation of evidence (optimal fasting time) requires understanding of the delivery of health care to patients undergoing surgery in complex social systems such as hospitals. This requires a theoretical explanation of the development, implementation and establishment of healthcare practices and processes such as fasting practice. Therefore, social phenomena are interpreted here as decision-making individuals interacting autonomously in an increasing complex manner from which other behaviour or structure emerges, so the implementation of guideline recommendations for fasting cannot be located to a single individual. Feedback continues bottom up and top down from these emergent structures to maintain or evolve fasting practice over time.

Applying the core concepts to the process evaluation themes

The three overarching themes that emerged from applying the framework of core Complexity Theory concepts to the process evaluation findings categorized into limiting factors, communication and history were; the impacts of system limiting factors, communication and interaction between individuals and departments and the historical aspect of fasting practice (Table 1).

1 **The impact of system factors to limit (inhibit) the evaluation and implementation of the guideline recommendations** were identified as factors that impinged on the effectiveness of the trial itself and the implementation strategies. Priorities and competing initiatives for individuals, teams and organizations, which is a common occurrence in healthcare systems, were key limitations in conducting this implementation trial. Many participating

sites did not adhere to their own existing fasting policy, which was consistent with the guideline recommendations. Therefore, something was overriding the individual site fasting policy.

2 **The impact of communication and interaction between individuals, teams, departments and professions on the evaluation and implementation of the guideline recommendations** refers to the nature of communication and the co-operation of individuals within and across professional groups, which was a key area of difficulty identified in the process evaluation data. Managing a patient's fast involved multiple healthcare professionals along the surgical pathway, and day surgery patients managing their own fasts at home. Therefore, implementation of system practice is a collective activity, not reliant on an individual.

3 **The impact of the longevity of traditional fasting practice in the face of accepted credible evidence to change the practice.** Awareness of the evidence base has been well known in anaesthetics, since at least 1993 (Strunin 1993). Maltby (2006) on questioning the rationale for the established NBM practice in the 1970s, was told:

….simple to write, straightforward for nursing staff to follow and easy for patients to understand and if a cancellation occurred, there was no problem with operating on another patient earlier than planned'……….The order was well established by tradition and traditions are difficult to break. (Maltby 2006, p. 367)

The key incentive to manage the operating list, illustrated here, relied on system adherence to the most efficient practice of NBM. This was a prevailing finding throughout the study. This tradition, or habit, proved difficult to change.

The application of Complexity Theory as an explanatory lens assumes decision-making individuals interact autonomously in an increasing complex manner from which other behaviour or structure emerges. This suggests that pre-operative 'blanket' fasting (see Glossary) is an emergent practice now maintained to ensure the efficiency of the operating list. Therefore, as an emergent practice, it cannot be easily dismantled. A new incentivised practice needs to emerge.

Applying the social complexity theory lens

In the following section, we examine how the core Complexity Theory concepts help explain social complexity in this specific healthcare context drawing on the three overarching themes above.

Table 3 Formation of core concepts.

Core concepts from Table 2	Core concepts	Elaboration of concept
- Open systems fluctuating - No centralized control - Health systems evolve in a self-organizing interaction of co-operation and competition between agents connected within the system - The system adapts to influences within and beyond its boundary	Self-organization	1 The phenomenon of **self-organization** is central to the understanding of the behaviour of complex systems. Self-organization means that there is no 'external controller' and that the system organizes from within itself in response to its external environment. However, complex systems are open systems and therefore the observer defines the boundaries of any system. Smaller complex systems are nested in larger systems in which they interact and respond to the influence of the behaviour of either the larger or smaller system.
- Interaction, feedback, continual transformation - There is a continual cause and effect from human agency interaction on the social structures and the social structure has causal power on human agency - Interaction results in emergent structures that have causal influence on the individuals - Interaction through communication in a continual evolution - Interaction within social relations (practice) is emergent from social interactions facilitating, limiting and regulating social practices.	Interaction	2 **Interaction (feedback)** in a complex system is the bidirectional transfer of information from one decision-making agent (individual human) to another. This information can be enhanced, suppressed or altered leading to an impact of this effect overall on the system. These interactions will be non-linear (asymmetric) and paradoxically, large changes can have a small effect, whereas small changes can have a large effect. However, greater interaction creates greater system complexity. The transformative process of human communication and relations (use of language conveying thought processes resulting in behaviour) underlies social interactions and organization of social systems. Furthermore, Johnson (2011) and Mitchell (2009), qualify that this system interaction is incentivised.
- Emergence into larger social structures - Interaction within social relations (practice) is emergent from social interactions facilitating, limiting and regulating social practices - Social structures are emergent from ongoing interaction human - The social systems cannot be disassembled into its parts	Emergence	3 The self-organization of the system through interaction leads to greater complexity and a primary characteristic referred to as **emergence** of behaviour or phenomena that is distinguishable from the interactions of individuals. Individuals do not have a complete schema of the 'whole' system for which they are a part. The system collectively functions on the information 'distributed' among the individuals. This constant process of feedback, interaction and emergence results in the evolution of the system and its adaptation. The emergent property cannot be dismantled to its constituent parts.
- System history - These agents are constrained by their history - Social process are historical	System history	4 **System history** refers to system sensitivity to its starting point. The key to system history is that although the system continually transforms overtime its origins suggest a 'boundary' within which the system responds, maintaining an adherence to trace 'behaviour's' (Cilliers 1998), such as 'habits'.
- The emergent social structures have an autonomy that is separate from the individual constituents - Social processes cannot be reversed - Continual transformation - Open systems fluctuate	Temporality	5 Complex systems are always in a constant state of flux between stable and unstable system states, emergence and transformation of the system, with increasing complexity and reactivity through feedback processes overtime, hence the importance of **temporality**. Systems also have periods of 'stability' and create stable structures. Therefore, observation of the system is temporally located. Complex systems do not reach or maintain a state of equilibrium (fixed point).

Self-organization

Healthcare practices, such as fasting, are not owned by any one individual or group of individuals, although they appear to be initiated or led by individual professionals. Practices are developed and retained in response to demand and the needs of the system to sustain itself. Competing priorities are a constant reality in health care. A self-organizing system will seek to remain efficient, following the shortest route (prioritising), not necessarily the 'best', 'evidence-based' or patient-centred. Fasting is an extensive common practice that appeared to be disconnected from individuals and not 'centrally controlled':

No the Trust (hospital) didn't really have anything to do with it [implementing the fasting guideline] I suspect the wider hospital doesn't really know much about it. The wards do but they don't care about the nuts and bolts of it... Anaesthetist (Site C)

The trial illustrated that the 'hold' for established practice was strong and required more than a response from a small number of individual champions (anaesthetists and nurses), although patchy implementation was observed. Sustainability is a known implementation issue (Wiltsey Stirman *et al.* 2012), which often relies on more than a push from an initial small set of individuals.

Interaction (feedback)

Key to the phenomenon of feedback is that it creates a flow of information throughout the system. Information can be transformed as it flows through complex, multi-level, non-linear communication networks. This transformation can be facilitative, inhibitive or unintended. It was observed in the study that local champions had varying degrees of impact on engaging their colleagues in the study and in changing practice to favour individualized fasting times for patients. The distributed nature of fasting practice in the system indicates that individuals leading and participating in the delivery of the interventions were not able to have knowledge of the whole system, as assumed with Complexity Theory. Therefore, the patchy nature of implementation and the focus on singular or small groups of champions interacting in the system was insufficient to counteract the incentive to maintain the management of operating lists, which led to prolonged fasting. There was a clear indication that the embedded practice of blanket fasts could not be overturned without a re-evaluation of the management of the operating list. It is known, at some point, when a patient is expected in theatre, therefore the crucial feedback point is whether this is communicated back to the ward or day unit nursing staff to allow adjustment to the patient's fasting time. This requires an additional step in the process and is thus, in Complexity Theory terms, less efficient.

Emergence

Emergence is a bottom up phenomenon. Complex systems can be resistant to large changes (top down) (Cilliers 1998) but more responsive to small changes that diffuse throughout the system affecting, over time, a more substantial change, although it may not be as originally envisaged or predicted (Johnson 2011). A key limiting factor was the low level of priority given to the issue of peri-operative fasting by the surgical departments, this suggested it was not deemed a change that would facilitate efficiency and therefore was not incentivised:

'...there's quite a lot going on in this Trust.... [hospital] it's probably low on peoples priority lists, you know when people are sort of fighting to keep their beds and things, I think it's just come at a bad time. I'm not saying it's not a worthwhile project'. Anaesthetist (Site M)

The diffuse nature of fasting practice management along the surgical pathway would demand a high level of interaction to establish an emergent practice of individualized fasting regimes. Minimal or inconsistent interaction with a change that requires a large number of individuals to embed that change seems certain to inhibit the desired emergent practice.

System history

Complex systems retain traces of their former histories but, because they are continually evolving with increasing complexity, they cannot be dismantled and reassembled like machines. The power relations between the different professions observed provided an example of retained (habitual) behaviour. Nursing staff provide a consistent presence to patients in the pre- and postoperative periods. However, they were not very often delegated the authority to make decisions on fasting. It is suggested that historical social dynamics were retained as observed by this professional power play:

One of the reasons the nurses wouldn't engage is that although there are guidelines circulated and recognized, when push comes to shove, the people in charge of the patients and the surgical lists – i.e. the surgical consultant will not change their practice..........if they [nurses] get it wrong then they can get into a lot of difficulty and quite a lot of abuse from irate doctors, because they've messed up the theatre list, basically.

Anaesthetist (Site J)

Temporality

Complex systems are not static but in constant flux. A key feature of healthcare organizations is that they are perpetually dealing with changes via policies, target setting and responses to a multitude of healthcare practices (evidence-based or otherwise) being updated or reconfigured. Prioritizing is a mechanism by which systems handle the level of information entering the system. Hence, non-prioritized information is 'lost' or not used. Systemic practice such as fasting is not reliant on individuals; it sustains over time beyond individuals and is how the system practice sustains. The process evaluation identified potential intermediary steps towards changes in practice; however, these were not developed enough in the 6 months allocated to intervention implementation to have made observable impacts on the primary outcome of average duration of patient fast period prior to anaesthesia.

Discussion

Boaz and colleagues (2011) state that research attempting to establish the most effective strategy to implement evidence-based guidance continues to be 'uncertain' or inconclusive (Boaz *et al.* 2011). Addressing complexity in 'real world' healthcare research and intervention complexity in context (complex systems) is a growing field (Lipsitz 2012, Anderson *et al.* 2013, Marchal *et al.* 2013, May 2013). In summary, attempts to 'change' and 'implement' a revised fasting evidence-based recommendation were thwarted by the resistance to current practice being 'dismantled' due to its embedded habitual nature. Fasting times before induction of anaesthesia have evolved to maintain efficient management of the operating list. Practice champions had some impact locally but were not able to embed recommended practice across the targeted surgical departments. To change practice requires identifying 'system' incentives and a better understanding of the embedded practice and its role in the surgical care pathway.

Furthermore, the PARHIS conceptual framework and the production of clear brief guidance using recommended strategies (Grimshaw *et al.* 2004, Rycroft-Malone *et al.* 2012) did not result in the expected change in practice. The role of individuals was not an explicit part of the PARHIS framework; however, the findings indicated the dynamic interaction of individuals in the health system was an influencing factor (Rycroft-Malone *et al.* 2013). This paper adds an explanation for the micro interactions of individuals and the practices and processes formed as organizationally embedded structures. Greater theoretical scrutiny is required to explain the relationship between practice history, the organization of practice and how embedded practice can change.

The ambition of Complexity Theory is to challenge long held scientific assumptions, allowing a different worldview to address a wide range of complex problems that require interdisciplinary collaboration (Mitchell 2009). Complexity Theory can provide a more general explanatory framework that encompasses more specific and middle range theories (Greenhalgh *et al.* 2010). This theory does not predict but explains the actual emergent behaviour (Cilliers 1998). Intentionality (goals, motivation and strategy) and the power relations of human agency are important aspects when applying Complexity Theory to social systems, although the overall design that actually emerges may not be as intended (Cilliers 1998) by the individual(s).

Many studies highlight the complexity of the social context in healthcare systems, including studies examining multiple agents across varied contexts (Chenot *et al.* 2008, Kirsh *et al.* 2008, Stetler *et al.* 2008, Dobbins *et al.* 2009) and their navigation in implementation research (Kilbourne *et al.* 2007, Bowman *et al.* 2008, Van Dijk *et al.* 2011, Gagliardi & Brouwers 2012, Kennedy *et al.* 2012). We propose that the application of Complexity Theory has the potential to provide a 'joined up' approach to understanding the inter-connectedness of the macro-function and structure (organizational) and micro (individual) interactions in the social healthcare context using the process evaluation findings from a cluster-randomized trial as an exemplar.

Moran (2007) refers to Complexity Theory as the transdisciplinary science, which requires us to address the relationship between the parts and the whole. The 'lens' being applied here shifts the gaze from part or object to relations, connections and how that creates structure and function. The nature of incentive and power are key properties of influence.

In the healthcare sciences, there is burgeoning literature that refers to complex interventions their description, development, theory and synthesis (Medical Research Council 2008, Anderson *et al.* 2013). In adopting the language of complexity and differentiating complicated and complexity, complex interventions are described by their wholes, parts and powers (Clark 2013).

May (2013) illustrates the potential utility of moving towards an explanatory theory in the healthcare context in his paper, 'Towards a general theory of implementation' (May 2013). He extends Normalisation Process Theory with four constructs that characterize implementation as a social process. Similar underlying assumptions on the nature of social processes involve the interacting, emergent and collective action of human agency (decision-making agents) in 'continuous and interactive accomplishment –rather than

final outcome' (May 2013, p. 1). This fits with Stacey's Complex Responsive Process (Stacey 2003). The object of implementation (complex intervention) is described as an 'ensemble of material and cognitive practices' which involves 'social mechanisms' (May 2013, p. 1). May's theory seeks to explain the context and contingent nature of the social healthcare system and that the implementation process may spread across macro- and micro-levels. Similarly, we propose addressing social system wide phenomena in the healthcare context of implementation of evidence-based guidance that operates under certain rules of complex systems that certainly pertain to the more specific aspects of social processes identified by May (2013).

Changing practice

The application of Complexity Theory to the social healthcare context for implementing evidence-based practice change suggests new fasting practice would need to emerge from within the system, self-organizing from the micro (individuals) to macro-levels (sub systems, organizational structures). This emergence requires incentivising a new practice (Plsek & Wilson 2001, Marchal *et al.* 2013). Therefore, assumptions of simple causal relationships when addressing diffusion of new practice in whole systems are challenged (Greenhalgh *et al.* 2004). Figure 1 speculates

how the Complexity Theory concepts link to implementing new practice as illustrated in this study. Initiation of new practice, such as individualized fasting times needs to diffuse throughout the surgical 'system'. This requires an incentive to do so, which counters the practice of maintaining blanket fasting practice. The incentivised new practice emerges out of the collective action of healthcare staff co-operatively communicating across wards, units, theatres etc. to counter the old practice and becomes the diffused, system wide embedded practice. This becomes a stable structure and part of the feedback loop stabilizing ongoing practice (see Figure 1).

Strengths and limitations

A critique of the utility of Complexity Theory as applied to the healthcare context raises the point of the capacity for control by either top down or bottom up implementation of a self-organizing system (Paley 2010, Tenbensel 2013). There are debates regarding the suitable appropriation of Complexity Theory to healthcare social systems (Greenhalgh *et al.* 2010, Haggis 2010, Keshavarz 2010, Paley 2010, 2011). Similarly, it has also been proposed that it is not well suited to the task of explanation, because explanation requires a Newtonian prediction (Tenbensel 2013), based on deductive reasoning. However, abductive reasoning seeks
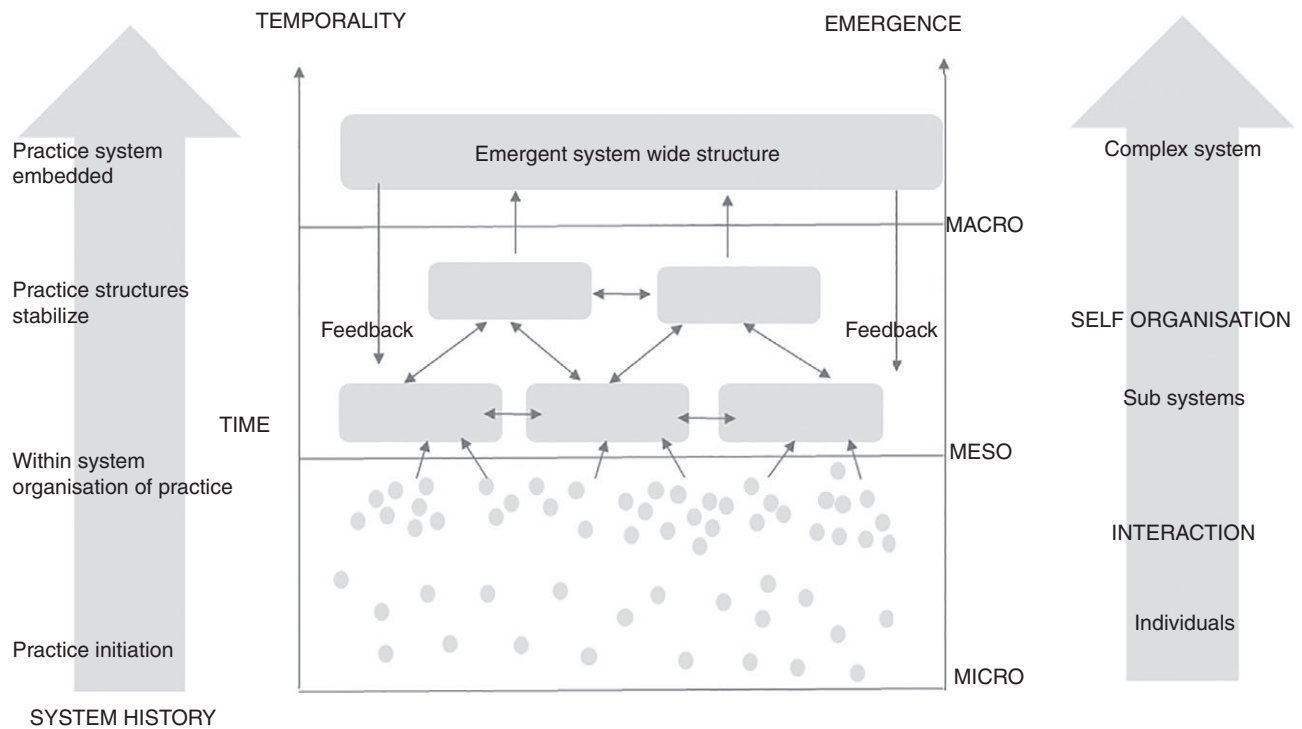

Figure 1 Practice development within complex systems.

the best or most plausible explanation for observed phenomena (Douven 2011) and provides 'explanatory inference' (Godfrey-Smith 2003). The application of this theory, inevitably raises questions, for example, how is complexity in complex systems best measured (Mitchell 2009), particularly if predication is paramount for decision-making in health sciences, whether the theory is applied as a metaphor or model (Kernick 2004), an interpretative approach or describes real phenomenon (realist) (Bryne 1998, Byrne & Callaghan 2013).

We propose that whatever the context or system under observation there are phenomena (Complexity) common across all types of systems, including social systems. The application of the core concepts provides additional and plausible explanation for limited implementation of guideline evidence. The concepts could assist in learning and development of future strategies. This may permit a degree of within system manipulation, rather than a managed system (Kernick 2004). Furthermore, once an action leaves the will and intention of the initiator it enters the system of interactions that can impede, alter or facilitate its trajectory (Moran 2007).

This theory synthesis provided a high-level abstraction of Complexity Theory concepts to make them more accessible for application (Pound & Campbell 2015).

Recently, further published examples of the appropriation of Complexity Theory to health care indicate the level of interest in applying the insights of this theory to multiple aspects of health care (Lanham *et al.* 2013, Strumberg & Martin 2013, Trenholm & Ferlie 2013). Further worked examples are needed in different health contexts to evaluate the extracted core concepts.

Conclusion

Complexity Theory is a trans-disciplinary science of particular relevance to nursing that addresses the development of increasing complexity in systems. It seeks to explain system formation, the connections and relations between the whole and the parts of the system. Extracted concepts developed to assist application of this theory in the social sphere of the healthcare context of implementing evidence-based guidance are self-organization, interaction, emergence, history and temporality.

Glossary

Pre-operative 'blanket fasting' refers to the practice of patients on morning, afternoon, or all day lists being fasted at the same time, as if first on the list, e.g. 6 am for a fluid fast that starts at 8.00 am.

Conflict of interest

No conflict of interest was declared by the authors in relation to the study itself. Note that Jane Noyes is a *JAN* editor but, consistent with usual practice, this paper was subjected to double blind peer review and was edited by another editor.

Author contributions

All authors have agreed on the final version and meet at least one of the following criteria [recommended by the ICMJE (http://www.icmje.org/recommendations/)]:

- substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data;
- drafting the article or revising it critically for important intellectual content.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site.

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