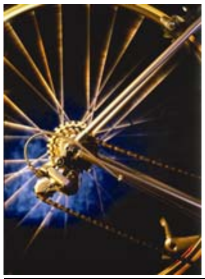

ANU
THE AUSTRALIAN NATIONAL UNIVERSITY

AUSTRALIAN PRIMARY HEALTH CARE RESEARCH INSTITUTE

COMPLEX ADAPTIVE SYSTEMS: A DIFFERENT WAY OF THINKING ABOUT HEALTH CARE SYSTEMS

A BRIEF SYNOPSIS OF SELECTED LITERATURE FOR INITIAL WORK PROGRAM – STREAM 1

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Introduction

Health care organisations have traditionally been viewed as if they were like machines that operate in accordance with the Newtonian laws of cause and effect, with linear relationships between actions and results. This classic, reductionist perspective has led to a managerial focus on getting the pieces to fit together, predicting future outcomes of managerial actions and controlling the behaviour of workers to get them to perform as cogs in machines (McDaniel and Driebe 2001). However, it is increasingly evident to administrators and researchers that health care organisations do not meet such mechanistic expectations – they are much 'messier' and more complex than this model suggests.

Complexity science has long been used to describe and explain behaviour in natural and biological systems, characterised by nonlinear dynamics and emergent properties based on diverse populations of individuals interacting with each other and capable of undergoing spontaneous self-organisation (McDaniel and Driebe 2001). Recent research in organisational management, behavior and psychology indicate that human systems also behave in a complex fashion (Dooley 1996). Complexity science is now being used to improve our understanding of health care organisations and systems (Plsek 2003). The operational model of complexity science – what Dooley (nd) calls complexity in action – is Complex Adaptive Systems (CAS). CAS theory provides a different way of thinking about health care organisations and systems, including how policy should be developed for them (Eoyang, Yellowthunder and Ward 1998), how they should be managed (Plsek and Wilson 2001), how innovation can be spread within them (Plsek) and how they should be evaluated (Eoyang and Berkas 1998).

Complex Adaptive Systems

A CAS is "a collection of individual agents who have the freedom to act in ways that are not always totally predictable, and whose actions are interconnected such that one agent's actions change the context for other agents" (Plsek 2003:2). Thus CAS are defined in terms of their component parts, the behaviour of those parts, the relationships between the parts and the behaviours (or properties) of the whole (Eoyang and Berkas1998).

CAS are made up of *agents*. In a health care system these might include individuals such as clinicians, patients and administrators; small organisations such as general medical practices; processes such as nursing and medical processes; functional units such as nursing, accounting and marketing; and large organisations such as hospitals, regulatory agencies and insurance companies (McDaniel and Driebe 2001). Their shared characteristic is that they are all 'information processors' - they can process information and adjust their behaviour accordingly. Agents all have information about the system but none understands it in its entirety (McDaniel and Driebe 2001). Agents in a CAS are diverse. This diversity is the source of novelty and adaptability in the system (McDaniel and Driebe 2001)

Agents are connected to and exchange information with others in the system through a complex web of *relationships*. These interactions and the interconnections that facilitate them are the most important aspect of a CAS (Eoyang and Berkas 1998; Plsek and Wilson 2001). CAS relationships have been described as *massively entangled* (Eoyang and Berkas 1998) because the component parts of the system and the variables describing those parts are large in number and interrelated in complex ways. The diversity, extent, intricacy and strength of the relationships influence the system's ability to adapt. There can be too much connectivity, as well as too little (McDaniel and Driebe 2001).

Agents respond to their environment using internalised 'short lists of *simple rules*' that drive action and generate behaviour (Eoyang and Berkas 1998; Plsek 2003). The rules need not be shared, explicit, or even logical when viewed by others, but they nonetheless contribute to patterns and bring coherence to behaviours in complex systems. Deliberately exposing and changing underlying simple rules leads directly to innovative ideas (Institute of Medicine 2001). In addition, short lists can be used *proactively*. When a new system is being instituted, a short list of simple rules (or minimum specifications) may be the most effective way to bring about change. They set the parameters and provide both focus and freedom for system activities. Over-prescription is counter-productive because it stifles creativity and innovation.

Together agents, their behaviours and their connections create a system that has a number of CAS-defining properties.

A CAS is *dynamic***,** which refers to "the continual presence of multiple interactions and their accompanying surprises, challenges and responses both within the system and between the system and its environment" (Miller et al; pp). Change is influenced by the number of agents, their rules of behaviour and the strengths and diversity of the relationships between them. Change is also discontinuous, with periods of stability and periods of change - the latter occurring at different rates at different times. The state of the system at a given time is a nonlinear function of the state of the system at some previous time (Plsek 2003; McDaniel and Driebe 2001). At no time does the system come to a natural equilibrium or stopping point (Eoyang and Berkas 1998).

Two other properties of CAS – self-organisation and emergence – are somewhat confusingly intertwined. Though McDaniel and Driebe (2001) attempt to define them separately, according to Eoyang and Berkas (1998:7) CAS exhibit "emergent or self-organising behaviours". New structures and forms of behaviour emerge that cannot be obtained by summing the behaviours of the constituent parts, because new system properties emerge from the nonlinear interactions between agents. The independence and individuality of agents processing information and behaving according to their simple rules can generate unpredictable behaviour. Compromise and cooperation result in workable solutions in the context of conflicting needs and constraints. This dictates that emergence cannot be controlled or predicted. Further, one agent's actions change the environment for other agents (Plsek and Greenhalgh) – a property Eoyang and Berkas (1998) call transformation - and surprising and innovative ideas can emerge from unpredictable corners of a complex system. There is no way of telling ahead of time what the emergent properties of the CAS will be, and an apparently trivial difference in the initial state of a system can result in enormously different outcomes (sometimes called the "butterfly effect."). On the other hand, large efforts to change a CAS may result in no changes – the CAS may demonstrate "robustness to external influence" (Love and Burton 2004). Inputs are not necessarily proportional to outputs (McDaniel and Driebe 2001). How the system evolves is dependent on its (irreversible) history (Dooley nd). Together, these processes create order in a CAS. Thus order is emergent as opposed to predetermined.

CAS are embedded within and bounded by other CAS with which they *co-evolve* – they not only change but also change the world around them (McDaniel and Driebe 2001; Plsek 2003). This is related to Eoyang and Berkas' (1998) transformation, which they define as operating both within and across system boundaries.

CAS operate simultaneously at multiple levels or *scales* (Eoyang and Berkas 1998). "One example of such a property is the presence of similarity at different scales. This phenomenon is widely present in nature, for instance in the ruggedness of a rocky coastline, which is essentially similar whether viewed by standing over a rock pool or observing a continent from space." (Love and Burton 2004)

The boundaries between agents within systems and between systems are open and complex – they are said to be 'fuzzy' (Plsek and Greenhalgh).

The properties of CAS described above are all dependent on *feedback loops* – the movement of information between agents and between systems. Feedback loops generate both change and stability in a CAS in that they fuel the interdependence of the system by keeping the parts synchronised, and simultaneously support evolution of the system by providing impetus and resources for adaptation. The more diverse and extensive the range of feedback loops in place, the better decision-makers can learn from the system and adapt to its emergent needs and characteristics. Each feedback loop becomes a focal point for observation, measurement, assessment and intervention. The nature of such loops will depend upon both the prevailing environmental context and the level at which they are implemented. Data collection is therefore critical for decision-making in a CAS.

Conclusion

This thumbnail sketch has identified and defined some of the components and properties of CAS. CAS theory provides a different way of thinking about health care organisations and systems, including how policy should be developed for them, how they should be managed, and how they should be evaluated.

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