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Kieren Diment
University of Wollongong, kdiment@uow.edu.au

Ping Yu
University of Wollongong, ping@uow.edu.au

Karin Garrety
University of Wollongong, karin@uow.edu.au

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Abstract

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Keywords

information, complex, preliminary, adaptive, investigation, systems, model, explaining, organisational, change, caused, introduction, health

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A Preliminary Investigation of Complex Adaptive Systems as a Model for Explaining Organisational Change Caused by the Introduction of Health Information Systems

Kieren Diment[1], Ping Yu[1], Karin Garrety[2]
[1]Health Informatics Research Lab, Faculty of Informatics, University of Wollongong, NSW, Australia

[2]School of Management, University of Wollongong, NSW, Australia

Abstract
This paper documents the preliminary development of a framework for evaluating organisational change processes during the implementation of an electronic nursing documentation system in residential aged care facilities. It starts with a brief outline of organisational change processes. This is followed by a more detailed exposition of the principles underlying complex adaptive systems (CAS) theory, where we explain how mathematical concepts can be used to illuminate qualitative research approaches. Finally we present some preliminary findings on the facilitators and barriers for the introduction of the electronic documentation system, explained with reference to the CAS theory, based on analysis of interviews with care staff members in a residential aged care facility. While there are clear benefits from electronic nursing documentation, we also identified significant risks, and possible unintended consequences, both positive and negative.

Keywords: Organizational Change, Nursing Records, Nursing Care Management, Complex Adaptive Systems, Residential Aged Care

1. Introduction

This is a report on the preliminary work examining changes associated with the implementation of an electronic nursing documentation system in a number of aged care facilities in South Eastern New South Wales and Queensland. The research reported in this paper is the beginning of a multi-organisational study of multiple sites within each organisation examining the change management practices and their consequences. In a sense this means that we have a natural experimental system with an unbalanced block design, although our research is not a formal experiment. To understand the change management issues arising from the implementation, our analysis is conducted at two levels: the variation among sites within each organisation, and the variation among the partner organisations. At this stage we have conducted interviews with nursing staff at all levels at a single site. This paper documents our theoretical approach to interrogating data about change based on the theory of complex adaptive systems approach [1]. It provides a case to show our approach at one aged care organisation.

Nursing documentation is a part of the clinical information stream in nurses' every day work. It provides a systematic process for nursing practice encompassing assessment, definition of patient problems, recording of nursing aims, planning of nursing tasks, execution of these tasks, and evaluation of care and care planning [2]. The perceived benefits of electronic nursing documentation systems in aged care are freeing up carers time by streamlining the process of documentation, improving its accuracy, and allowing more time for direct care. However

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scientific evidence for this perception is lacking [3]. Understanding the processes of change and how the actions of individuals and collectives effect the changes which occur when electronic nursing documentation is introduced into residential aged care facilities can help identify the variables and underlying processes that can help lead to answers to the above perceptions. As well as providing a triangulation for the scientific findings concerning the implementation of electronic nursing documentation, a full-scale qualitative, ethnographic exploration of the change process can reveal the causal relationships and outcomes of introducing the electronic nursing documentation system into an organisation. In order to develop the framework for evaluation of organisational change process, the components of organisational change is first reviewed.

1.1. Components of Organisational Change

The study of organisational change in health informatics can help inform the decision making process. Lorenzi's seminal article [4] outlines the issues related to change that occur during implementation, which may influence the trajectory of success and failure. Lorenzi notes that these concepts are not easy to define, as they can be framed in terms of success/failure, or more general ideas of process. The non-linear trajectory of change, and its significance in explaining change, is also worth noting: the non-deterministic nature of change, and that similar starting conditions can result in substantially different outcomes helps elucidate the value of context within the situations under study [5, 6].

Organisational change can be seen as encompassing three components: people, culture and processes, defined as follows:

- **People** - demographics, structure of the workforce, educational background, and dispositional factors such as motivation, personality and performance
- **Culture** - values, leadership, and workplace rituals
- **Processes** - documentation, work routines, and chain of responsibility

These components overlap. For example in nursing practice, handover is a central process for the sharing of knowledge and dissemination of information. However, it is also an essential part of workplace culture. The personal dimension is also important in shift handover – here an individual registered nurse is in charge of delivery, and the personality and professional skills of each staff member can influence the process.

The rich interactive nature of the workplace manifested through business processes such as handover are difficult to make sense of, because they can have unpredictable consequences. At this point we discuss Complex Adaptive Systems (CAS) theory, and the way that this ontological framework can help to make sense of the change phenomena under investigation.

1.2. Complex Adaptive Systems – Complexity, Chaos and Entropy

Macquire et al. [7] give a detailed definition of complex adaptive systems: *"A complex [adaptive] system is a whole comprised of a large number of parts, each of which behaves according to some rule or force that relates it interactively to other parts. In responding in parallel to their own local contexts, the parts can without explicit inter-part coordination or any one of them having a global view [although a global view, or partial global view is not mutually exclusive to complexity], cause the system as a whole to display emergent patterns at the global level – the emergence of orderly phenomena and properties of the whole that cannot be predicted from properties of parts".*

This theory has its roots in mathematics, and as a result its components are very well defined in a mathematical sense. One important aspect of complex adaptive systems are emergent properties, one form of which is unintended consequences. The challenge for social researchers wanting to use this framework is translating these mathematical ideas into concepts amenable to qualitative analysis. High levels of uncertainty with respect to the precision with which variables or situations can be identified, measured and assessed are also problematic. One approach to CAS is to use biological ecosystems to illuminate organisational processes. Dooley's paper [1] is perhaps the most widely cited example of this approach.

The theory of Complex Adaptive Systems has also been used in health information systems research e.g. [8, 9]. McDaniel and Dribe [10] discuss the problems experienced by researchers in preventative health, who take a reductionist, mechanistic approach to continuous quality improvement in preventative health work. According to the McDaniel and Dribe's analysis the assumption that healthcare organisations are machine bureaucracies may be incorrect, and re-casting the system as a set of loosely coupled interacting components can improve understanding of how to achieve an optimum outcome. Stroebel et al. [11] suggest an assessment process to guide reflective practice, and based on this perceived need to account for the inherent complexity within the workplace. However, the evidence of the effectiveness of this approach does not yet seem to be supported by substantial evidence, perhaps due to a lack of detailed case studies in the area.

While the use of biological concepts such as ecosystems and autopoesis (self organising systems) are described and applied by Dooley [1], there is an attempt to examine the underlying role of complexity and interdependence inherent in the CAS view. However, the biological ecosystem view of organisations has been justifiably criticised for its lack of clear connection between the biological concept of species and a corresponding unit of construction in human organisations [12]. Nonetheless, there is some recognition of the potential of CAS in the human sciences, as well as in the field of health informatics. Therefore, we will attempt to apply the CAS to our case study within the domain of

the introduction of electronic nursing documentation in residential aged care facilities.

We start with the assumption that while the biological approach to analysis of organisations is informative, there are no direct correspondences. Ecosystems (a type of biological system) and organisations are both constrained by resource limitations, by the internal structure of their interacting components and by their relationship to their external environment. However the economics of the underlying resources are substantially different. While ecosystems are generally limited by nutrient availability, the resource limitations for human organisations are based on material, financial and people constraints. What is common between the two systems is that the flow of these resources is an important driver of change and homeostasis. Therefore it appears that a direct analysis of the dynamic processes that underlie resource flows should be useful in defining a more robust conceptual basis for organisational ecology.

Baranger [13] provides an excellent non-technical summary of complexity theory which is outlined in the remainder of this section. Because Baranger's disciplinary perspective is informed by theoretical physics, while his writing remains close to the mathematical underpinnings of complexity theory, his grounding in application, along with his clear teaching skills is very instructive, as it provides us with a clear logical explanation of how to link the abstract mathematics of complexity to an applied dimension.

Complex Adaptive Systems are difficult to understand because of the interaction between two fundamental components – chaos and complexity. Chaos can be a property of simple systems (i.e. systems with few parameters), and the results of chaotic models are by definition intrinsically unpredictable. Baranger states that chaos is "that part of mathematics where calculus does not apply". One of the defining features of chaos is sensitivity dependent on initial conditions (e.g. in our study it may be that the initial training approach can vary between units in small ways, but that these small differences might have dramatic consequences). Complexity is different from chaos. The human body, weather patterns, and ecosystems are all examples of complex adaptive systems where the individual constituents self-organise, and the whole is greater than the sum of its parts. Emergence (as in emergent properties) is a phenomenon stemming from complexity where the organisation and interactions at one location in a system cause changes at another separate location. A system whose configuration is capable of changing over time is called a dynamic system. A dynamic model is a mathematical model or a set of rules describing the time dependence of a point's position in space (either physical space or a more abstract idea of space). A simple example of a dynamic system is the swinging of a pendulum. Chaos has a close relationship with complexity. Complexity has the property of multiple interacting components each of which may or may not be chaotic. The network of interactions is compounded by stochasticity (probabilistically determined variation). In thermodynamics, the statistical model of probabilistic variation is described by the concept of entropy.

Entropy is an important part of any system as it helps define whether a system is closed (independent) or open (dependent on other systems). In thermodynamics, the entropy (degree of disorder) of a closed system increases over time. High entropy systems have high levels of disorder, and the components of a high entropy system are generally seen as possessing disorder whose atomic configuration are uninteresting. However, the effects of a transient increase in entropy can be interesting. A substantial outage of the electronic documentation system of our study site is a good example of a transient increase in the rate of the accumulation of entropy. This will be discussed in the results section of this paper.

One fascinating property of entropy is that even in the physical sciences, it is a constructed concept, which is used to make "reality" more manageable. The smoothing procedure used for entropy analysis defines the scale beyond which the analyst is unable or unwilling to keep track of details. Smoothing represents a self-imposed (subjective) increase in the entropy of the system – the key to understanding this procedure is to optimise the level of analysis at which it is performed – that is, how should we group the data together in order to make conclusions in an efficient way. The results section of this paper, is an attempt to do this with our preliminary data. As our data consist of individual interviews, we need to understand the nature and quality of the data we gather, and at what level we maximise its meaning. This in turn allows us to improve our understanding of the flow of resources within the organisation.

Complex Adaptive Systems' quantitative roots do not preclude its use for solving qualitative problems. For example, a quantitative problem in electronics would be to calculate the change in voltage in a lighting circuit when a change occurs. A qualitative equivalent would be to determine whether the light bulb becomes dimmer or brighter as a result of that change. It should be clear that where the number of parameters is high, or measurement is uncertain, or where a chaotic system is suspected, a qualitative solution will be more achievable than the quantitative solution.

This brief summary should illustrate that CAS as an ontology (framework to generate meaning) may help bridge the divide between positivist and post-positivist: i.e. between the perspective that there is a "true" reality versus the idea of a socially constructed reality [14]. In the search for improved understanding in social research we need to evaluate this way of looking at things in order to determine how useful it is, and to determine whether this lower level of CAS compared to the organisation as ecosystem approach is useful in providing explanations of change processes.

2. Methods

2.1. Design

Semi-structured interviews were conducted at a single 100 bed residential aged care facility in South Eastern New South Wales over a two day period in early 2009. The interview guide was developed by the second author. The themes discussed in the interviews that were found to be relevant to the complex adaptive systems approach were: communication (e.g. the role of verbal and written communication), individual opinions about the electronic documentation (e.g. is the software used well?), workplace issues (e.g. the way that the electronic documentation affects work patterns) and training issues (e.g. the quality of the training and potential improvements to the training).

2.2. Sample

The two first authors interviewed 12 nursing staff and four allied health/care staff. Interviews lasted between 10 and 40 minutes depending on the detail of the answers provided. After interviewing managers, a convenience sample was used to interview care staff due to the difficulty of getting nurses off the floor. We interviewed the nursing manager and deputy manager, three registered nurses, three enrolled nurses, three recreational activities officers, one physiotherapy assistant and four personal care workers.

2.3. Analysis

Interview notes were compiled and consolidated, and emergent themes related to the complex adaptive systems perspective were identified for further exploration in the results section below. One of the purposes of this (initial) round of interviews was to trial the interview to assess its suitability for understanding organisational change at other sites. Notes were used as a quick way of understanding the issues pertaining to change, and the coverage that the interview guide gave to these questions.

The role of complex adaptive systems in the analysis were as *sensitising concepts* [15]. These are a conceptual overlay used to bridge the divide between sociological theory and empirical evidence. They provide a lens with which to examine the data in a way that is meant to address the theoretical concerns of the research in a way that can provide a theoretical framework for analysing the data. The idea of sensitising concepts is a sociological analogy for the concepts of a priori and post-hoc analysis commonly used in quantitative work. The reason that we need to make this distinction is as follows. In quantitative studies, there are well-recognised techniques to assess reliability, validity and measurability, which have good empirical and theoretical foundations. Establishing the empirical and theoretical foundations of qualitative study is much less straightforward, for reasons relating to the philosophical scepticism school of thought (see Blumer [15] for further details). As such, sensitising concepts arising from complexity studies outlined in the introduction provide a technique with which to assess the interview notes. This allows us to explore whether the complexity approach can inform our analysis of the organisational change. If the evidence supports this approach, further rigorous analysis of the interview data using transcripts, and a more formal coding procedure is likely to inform the change processes observed during the longitudinal study.

2.4. Ethics

Ethical approval was obtained from the University of Wollongong Ethics Committee. Permission was granted for the research to be conducted at the provider organisation.

3. Results

When the introduction of technology is the primary driver of change, a "technological imperative" can occur. In such a case, managers and other organisational actors have little control over the nature of the organisational change [5]. This technological imperative fundamentally alters aspects of the process dimension in the organisation we study, because at least some of the changes come from external technological pressures. This also means that some of the drivers for organisational change in our study are outside the direct control of management. In turn, this influences the change processes which occur during implementation. Concurrent with the introduction of information technology, there have also been changes in the funding model for aged care with the implementation of the Aged Care Funding Instrument (ACFI) in March 2008, which replaced the Resident Classification Scheme (RCS), the funding model used for the previous 11 years. The interaction between the introduction of ACFI, which results in substantially simplified documentation and assessment requirements, and the electronic documentation system has resulted in significant unintended consequences which will be discussed below.

3.1. Difference between managers' and carers' perspectives – Multilevel interactions

Senior staff members stated that improved access to documentation across the organisation facilitated information flow. This is a direct result of implementing the electronic documentation system. From the perspective of the CAS theory, the documentation system reduces the rate at which entropy in the information contained in the nursing documentation accumulates over time. The positive reaction to a more consolidated set of documentation by managers appears to be directly in line with the nature of their jobs. That is, as managers have more responsibilities than care staff, and a greater need to deal with large volumes of information, they had a clearer perception of the benefits

of the electronic nursing documentation. The interviewees with a managerial position (the service managers and the registered nurses) all appreciated the improvements to reporting and data access that the electronic system provides. However, our CAS perspective also emphasises the importance of interactions across the system. For example the improvement in consolidated information access acted concurrently with a change in the regulatory environment resulting in different consequences at different levels of the organisation. The personal care workers perceived that the change of residential aged care funding model from RCS to ACFI had reduced their documentation workload. This has had two effects. Firstly, with less use of the documentation, the nursing assistant staff relied more on verbal communication; secondly a limited number of available computer terminals may also result in a reduced opportunity to access nursing records by the personal care staff, thus reducing the use of documentation for retrieval of data as well as the reduced statutory requirement for entering data. However, managers tended to find the regulatory changes made it easier for them to assess the state of their facility, and they found it easier and more reliable to lodge funding claims. While some of these staff acknowledged that this could be a good thing as it allows them more time to spend with residents, there may be a sense of disempowerment at the junior level. On the contrary, the sense of the increased empowerment at the facility management level is obvious. This is an example of the change in work practices having different effects at different levels of the organisation, with clear positive consequences for managers, but at best neutral consequences for personal care staff.

3.2. The effect of system outage – an example of potential for entropy spikes in the system

The next part of the data that we wish to examine for this paper is the effect of a technology outage. A two-week outage was caused by a networking mishap between the off-site central server and the residential aged care facility. The mishap itself was out of the control of the organisation, but a lack of disaster recovery plan evidently caused a dependence on an external telecom provider to fix the problem. The site returned to paper records during this period. This increased risk, as older documents were not available, had resulted in many staff complaints, as staff members could only rely on oral communication to pass information around. If we view the electronic documentation system as a low-entropy, low-redundancy system, and the paper based system as its higher entropy counterpoint, we can see that the risks associated with local data loss are relatively high with electronic documentation if the data are only stored off site. In our interviews we also discovered a possible extra source of entropy increase from the effects of network lag. The electronic documentation system at this facility is web based, and concurrently the computer systems are all thin clients, therefore the capacity of the network is likely to be stretched at times of high traffic. While we suspect that the direct impact of this latter type of outage is likely to be small, it is another source of increased entropy in the electronic documentation system.

3.3. Responses to personal care workers' varying involvement in implementation and continuing use – an example of emergence.

A further issue that came from the interviews, which would be categorised as emergence would be the differing responses of personal care workers to their training. There is a potential problem in managing the personal care workers' relationship to the electronic documentation system that didn't exist with the paper-based system. There has been a trend towards reducing the documentation load of personal care workers since the replacement of the RCS funding system with the Aged Care Funding Instrument in May 2008. This was roughly one year into this site's use of their electronic nursing documentation system. With the RCS, personal care workers should have had daily interaction with the electronic nursing documentation system. By comparison, the ACFI requires much less frequent recording of progress notes, as funding is based on assessment results, not on the amount of documented care activities as in the old funding model, RCS. Independent of this change, the managers at this site had decided that the checklist-based documentation (e.g. shower and bowel records) should be done on paper due to user-interface limitations of the software package. Consequently, while these workers had to use the electronic documentation on a daily basis during the first year of operation of the system, their documentation load substantially reduced in the second year.

For the care staff who either like doing documentation, or like using the computers, there was a risk of alienating them by bringing computers into their working life, then due to changes in documentation requirements, subsequently removing the responsibility. This had been perceived by the small number of affected individuals as downgrading their level of job sophistication. Subsequently in later rounds of data collection, we have observed similar patterns arising from a different situation (e.g. after the training phase, personal carers who were trained through the train-the-trainer training, then essentially stopped using the documentation system). This is suggestive of the feature of chaotic systems – self-similarity. Self-similarity is the phenomenon whereby an object has a similar appearance at different scales, for example, a coastline. As this potential disengagement of a small number of personal care workers after their involvement in training other staff to use the electronic documentation system has been observed in different situations, we suggest that this may be an example of a similar outcome arising from the operation of different contextual factors across the different stages of implementing of the system. We have also observed strategies emerging from another aged care home to attempt to promote the use of computers

as part of a broader push to encourage personal carers advance to enrolled or registered nurses. More formal recognition of this can help encourage a career path for an occupation that suffers from the lack of long-term career prospects.

Future data collection can help better understand this idea of emergence occurring through creation of new workplace resources (e.g. computer skills, and engagement with the required documentation). Understanding how these resources flow through the workplace, the opportunities generated by their effective use, and the risks posed by not using them can help formulate recommendations for management, as well as helping to explore where these kinds of emergent unintended consequences can arise.

4. Discussion and Limitations

In this paper we used the preliminary data gathered from a residential aged care facility to evaluate a complex adaptive systems approach to understanding organisational change. The primary goal of the computer based record system is to improve quality and efficiency of nursing documentation, but the structure of the workers perceptions of the system appear quite different (and would be hard to predict in advance). Our CAS ontological framework does seem attractive as a way of explaining how this potential divergence of purpose and perception occurs. Central to this approach is the idea of entropy – the degree of disorder in a system increasing over time. Thinking about a traditional paper record, and the thick dog-eared folders of patient documentation that accumulate over time, there is clearly a substantial increase in entropy at many levels – in the quality of the paper as it becomes dog-eared, and in the search-accessibility of the information as it becomes more difficult to find. We have clearly demonstrated that while the electronic system is inherently lower entropy than the paper system, there is a certain amount of fragility in it, in terms of trouble dealing with transient and longer-term outages. Having the principles underpinning CAS to guide the analytic process appears to be helpful in performing a systematic analysis of how change occurs, and what factors are most important to ensure system success. The next step for this research project is to conduct more interviews across different sites, to achieve the research objectives.

The main limitation of this article is that these interviews were conducted at a snapshot in time, whereas change is a longitudinal process. Therefore we have no way of assessing the importance of the issues identified in this paper, and the way that they may change over time. A secondary limitation is that sampling from only one nursing home means that we are yet to be able to generalise our findings to other nursing homes.

5. Conclusion

The results of this preliminary study suggest that complexity, as a framework to understand the structure of our research problem, is a useful perspective which is compatible with the broader systems view of the firm favoured in some parts of organisation studies. This makes CAS an important theoretical framework for studying organisational change. In addition to other methods used in organisation studies and occupational psychology, we hope to provide a detailed and systematic process to describe and guide change management in the introduction of health information system into health and aged care organisations.

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Correspondence

Kieren Diment
Health Informatics Research Lab
Faculty of Informatics
University of Wollongong
Wollongong, NSW, Australia
Phone: +61 (0)2 4221 3606
kdiment@uow.edu.au