A Complex Adaptive Systems Perspective of Health Information Technology Implementation

Karim KESHAVJEEa,c,1, Craig KUZIEMSKYb, Karim VASSANJIc, Ahmad GHANYd
a University of Victoria, Victoria, Canada
b University of Ottawa, c InfoClin Inc, d McMaster University

Abstract. Implementing health information technology (HIT) is a challenge because of the complexity and multiple interactions that define HIT implementation. Much of the research on HIT implementation is descriptive in nature and has focused on distinct processes such as order entry or decision support. These studies fail to take into account the underlying complexity of the processes, people and settings that are typical of HIT implementations. Complex adaptive systems (CAS) is a promising field that could elucidate the complexity and non-linear interacting issues that are typical in HIT implementation. Initially we sought new models that would enable us to better understand the complex nature of HIT implementation, to proactively identify problems that could be a precursor to unintended consequences and to develop new models and new approaches to successful HIT implementations. Our investigation demonstrates that CAS does not provide prediction, but forces us to rethink our HIT implementation paradigms and question what we think we know. CAS provides new ways to conceptualize HIT implementation and suggests new approaches to increasing HIT implementation successes.

Keywords. Complex adaptive systems, interoperability, HIT implementation, process redesign

Introduction

There is increasing investment in information technology for health care to enhance healthcare delivery in North America and elsewhere [1]. To date the introduction of health information technology (HIT) into clinical settings has been problematic because of changes to care delivery workflows and unintended consequences. Several studies have examined the role and nature of these consequences from the perspective of HIT implementation [2-4]. Much of the current research on these consequences has focused on the negative aspects of HIT implementation including technology-induced errors [5], workarounds [4], power issues, workflow disruptions [2-5] and patient safety concerns [4,6].

The existence of these so-called unintended consequences emphasizes that we cannot look at HIT implementation as process centric (i.e. order entry or decision support) in isolation from other processes. Rather we need to look at the overall system that HIT is automating. Safe use of HIT requires a continuous monitoring of

1 Corresponding Author.
implementation over the continuum of providers who provide care, the patients who receive care, the organizational context in which care is provided, the tasks that are associated with a process, the environment within which the organization exists and other relevant processes and constraints [7].

Complex adaptive systems (CAS) are a means of looking at the complexity and interacting issues that define HIT implementation [8]. CAS can help reframe the thinking about HIT implementation and acknowledge the non-linearity of processes and how behaviors and tasks emerge as a result of non-linearity [9].

Surprisingly, a search for complexity theory and CAS within the health informatics literature yields a paucity of articles [8,9]. While these studies have suggested that HIT implementation issues are characteristic of CAS, they have not specifically looked at HIT implementation through the CAS lens.

The medication prescribing, dispensing and administration process is one of the most common sources of medical errors due to the complexity of the process and the significant potential for harm from potent medical interventions [11, 12]. Therefore it is an excellent process to study from the perspective of CAS. In this paper we analyze and link the prescribing process to CAS theory. This allows us to leverage the prolific research being done in other disciplines for gaining insight into developing a framework for HIT implementations.

1. Methods

We used a process model of prescribing and dispensing in the community that had previously been validated as part of AG’s Master’s thesis [unpublished] with key stakeholders, including physicians, pharmacists and members of the public as the use case for identifying CAS elements. Figure 1 shows a simplified version of the validated process model.

![Figure 1. Simplified medication prescribing, dispensing and administration process in the outpatient setting](image)

We analyzed the prescribing and dispensing process using the lens of CAS. We listed the features of CAS and identified instances of prescribing and dispensing which fit those features. Our goal was to identify a mechanism or method to predict unintended consequences and to predict areas of higher risk in HIT implementation.
2. Results

Table 1 maps features of the medication prescribing process to features of CAS.

Table 1. Features of CAS and Medication Prescribing

<table>
<thead>
<tr>
<th>Features of Complex Adaptive Systems</th>
<th>Corresponding Features of Medication Prescribing Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-linear processes</td>
<td>Changes in one area affect things in another area, but in non-linear and non-intuitive ways. E.g., decreasing drug-drug interactions leads to increased work for physicians. Some errors in prescribing are easily solved by pharmacists; others require a phone call.</td>
</tr>
<tr>
<td>Emergent behavior</td>
<td>Unintended consequences of HIT [2,3]. Workload shifts from pharmacist to physician when e-prescribing is implemented.</td>
</tr>
<tr>
<td>Feedback loops</td>
<td>Pharmacists phone physicians to confirm information. Physicians monitor drug effects and side effects. Patients revert to their physician or pharmacist if they face any issue with their medication.</td>
</tr>
<tr>
<td>Co-evolution</td>
<td>When physicians start printing prescriptions, patients experience a decrease in dispensing errors due to illegibility and pharmacists have to make fewer calls back to physicians to clarify the prescription. Overall, this leads to fewer phone-calls between providers.</td>
</tr>
<tr>
<td>Requisite Variety</td>
<td>Each network of prescribers, dispensers and patients has its own unique characteristics. There are no uniform methods for prescribing and dispensing. Changes that work in one network do not work in other networks.</td>
</tr>
<tr>
<td>Connectivity</td>
<td>Relationships and communication between physicians, patients and pharmacists is very important to ensure patient safety. The prescription is an important tool for communicating between prescribers and dispensers.</td>
</tr>
<tr>
<td>Simple Rules</td>
<td>Prescriptions have a very small number of elements, yet they can have far-reaching implications. The act of prescribing is made of several simple rules (the contents and process of a prescription) but the end-result is an information-rich document with far more complex interpretations and implications for patient health.</td>
</tr>
<tr>
<td>Self-organization</td>
<td>Pharmacists can monitor prescription problems and work with patients and physicians to correct them. E.g., during the recent large scale switching from one opioid to another in Ontario.</td>
</tr>
<tr>
<td>Non-discrete Boundaries</td>
<td>The prescribing process is regulated by licensing authorities and by legislation. These can have profound effects on prescribing and dispensing.</td>
</tr>
</tbody>
</table>
A review of Table 1 quickly demonstrates the futility of trying to predict the path and outcomes of an HIT implementation when there are large numbers of interacting variables with non-linear relationships between them. Even a downturn in the economy can cause a perturbation in an HIT implementation if strategic plans change because of financial issues.

The key insight to emerge from our analysis is that HIT implementations are inherently unpredictable and that unintended consequences are to be expected. Rather than trying to predict and control an implementation, CAS theory points to an approach that is more organic and iterative in nature: implement a small, minimally viable part of the HIT and observe the results (non-linear processes, feedback loops). Measure the impact of the implementation on key goals (i.e., develop new feedback mechanisms for the new system, watch out for emergent behaviours). Listen to nay-sayers and objectors, they may have useful advice to give and may be your best predictors of what could go wrong (self-organization, feedback loops). Make course corrections and adjustments (feedback, self-organization). Watch out for boundary issues such as regulations impinging on workflow (non-discrete boundaries). Don’t expect that what worked in one setting will necessarily work in another (requisite variety). Develop new mechanisms for communication, especially for meta-communication (connectivity). Implement some more. This approach is reminiscent of quality improvement approaches such as the Plan-Do-Study-Act cycle which has been a successful model for generating change in complex clinical situations and is also reminiscent of the lean start-ups movement which promotes the idea of continuous quality improvement with small, incremental changes.

3. Discussion

In this paper we advocate for using complex adaptive systems theory to study HIT implementation issues and to make recommendations on how we can improve the HIT implementation process. The real strength in complex adaptive systems is in the word system. Healthcare processes are not disparate entities that exist in isolation. Rather they are complex systems with multiple actors and parts that are not linear but are defined by variation and dynamic evolution. Complex adaptive systems acknowledge that complexity exists in a system because of the range of actors and the multiple ways that they integrate with one another while engaging in system processes. Modeling healthcare processes from the perspective of this complexity allows us to understand the impact that implementing HIT will have on a process such as how the burden of a task may shift from one provider to another or how the process may evolve over time.

The end point of our analysis is that CAS does not provide prediction, but forces us to rethink our HIT implementation paradigms and question what we think we know. CAS provides us new ways to conceptualize HIT implementation and suggests new approaches to increasing HIT implementation successes.

References


