Studying the HIT-Complexity Interchange

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Abstract. The design and implementation of health information technology (HIT) is challenging, particularly when it is being introduced into complex settings. While complex adaptive system (CASs) can be a valuable means of understanding relationships between users, HIT and tasks, much of the existing work using CASs is descriptive in nature. This paper addresses that issue by integrating a model for analyzing task complexity with approaches for HIT evaluation and systems analysis. The resulting framework classifies HIT-user tasks and issues as simple, complicated or complex, and provides insight on how to study them.

Keywords. Complexity, health information technology, usability testing, clinical simulation, naturalistic observations, technology-induced errors

1. Introduction

It is acknowledged that introducing heath information technology (HIT) into clinical areas is complex, particularly when workflows are impacted [1]. There is a wide body of research on unintended consequences that describe HIT implementation issues including communication issues, workflow issues, and contribution to or the creation of medical errors [2-5]. Sometimes unintended consequences arise as a result of interventions to address other problems. For example, while HIT was advocated as a solution to prevent medical errors [6], it actually became the driver for a new category of errors called technology-induced errors [5]. HIT issues are particularly problematic for front line clinical staff such as nurses.

Despite our best attempts at automating a complex environment we still have trouble predicting how people and technology will interact, resulting in a variety of unintended consequences as described above. A complex adaptive system (CAS) is a system that displays properties such as emergent behaviors, non-linear processes, co-evolution, requisite variety, and simple rules [7]. As a system becomes more complex, the number of components and interactions between each component increase, both within the system itself, and between a system and its surrounding environment [8]. Automating healthcare delivery through HIT is also a complex endeavor and could be informed by principles of complexity theory for understanding workflow and other aspects that are critical for HIT implementation [1]. Articulating workflow complexities and how to evaluate and design HIT to manage the issues is particularly relevant to front line clinical staff such as nurses [9].

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While it has been acknowledged that CASs can help us study, analyze and propose solutions for reconciling workflow and HIT implementation, an acknowledged shortcoming with using CASs for studying healthcare delivery is that it may simply be the new fad, or the 'emperors new clothes' [8]. Much of the current research on CASs is descriptive in nature and lacks methodological rigor on how CASs should be used to understand HIT design and implementation [10].

Evaluation approaches from usability engineering such as usability testing and cognitive task analysis have greatly enhanced our ability to understand how HIT needs to be tailored to fit the clinical context where it will be used [11-12]. It has been suggested that multi-modal approaches to evaluation, for example combining thinkaloud methodology with 'near-live' clinical simulation can enhance evaluation by providing an environment that replicates real world clinical settings [12]. While innovative usability approaches such as near-live evaluation have pushed the envelope of how we evaluate HIT, it works best if we can have an accurate model of the clinical environment. While the complexity of the clinical environment, and the impact it has on HIT implementation has been acknowledged, there are no studies that have combined elements of CASs and usability engineering to inform the design and evaluation of HIT.

This paper addresses the above shortcoming and integrates the Cynefin model of CASs with approaches for HIT evaluation and systems analysis. The results are an integrated framework that can be used to classify and study user-task interactions with HIT.

2. Methods

2.1. Case Studies and Conceptual Models

The authors draw upon several studies where they have looked at HIT implementation in a variety of contexts and settings including perioperative care, palliative care and handovers between units and facilities. Our conceptual framework integrates two models and a set of systems analysis approaches. First is a model for representing complex systems (the Cynefin Model) that represents complex systems as agent relationships, experience, and context from a systems perspective [13]. Second is a model that represents a continuum of system testing approaches ranging from usability testing through to naturalistic studies [14]. Third is the incorporation of methods for systems analysis of an environment where HIT is used.

2.2. Data Analysis

In each of our cases studies we first identified various tasks users do while interacting with HIT. We then identified issues that occur in the context of conducting the task and then categorized the issues as simple, complicated or complex as per three of the categories from the Cynefin model [13]. Simple issues are repeatable and predictable and they can be managed by developing best practices. Simple issues are managed by sensing, problem, categorizing and responding to a problem. Complicated issues are separated over time and space and may have multiple components and relations. While they can be modeled and replicated, they require systems thinking and analysis to articulate the issues so they can be managed. Complex issues are not predictable but

rather will evolve over time, unlike simple or complicated issues, which tend to be more stable. Complex issues require probing and sensing to understand the issues both initially and longitudinally over time. Fig.1 shows our conceptual framework and its two main aspects. On the left side, the Cynefin model is used for to define tasks and issues. On the right side, the tasks and issues are analyzed to enable understanding of them using HIT evaluation and systems analysis approaches, respectively.



Fig. 1. Conceptual framework for defining and understand tasks and issues

3. Results

In this section we provide empirical examples of using our framework. We describe simple, complicated and complex issues and how they would be studied.

3.1. Simple

Simple refers to defined and repeatable tasks and situations involving minimal interactions. Examples of simple tasks are defined data entry such as a patient surgical history as part of pre-operative assessment. The task is a one-to-one interaction between the nurse and patient involving one system and no additional interactions. One way of analyzing simple problems involving technology in health care is to apply basic methods from usability engineering such as usability testing and usability inspection. Both of these methods involve analyzing user interactions on tasks that are well defined a repeatable and involve minimal interaction with other users. Examples of such studies come from the work of Kushniruk and colleagues who have refined low cost rapid analysis methods for analyzing simple clinical situations involving health information technology such electronic health records and decision support systems [15]. For example, one could conduct usability tests with a nurse using a peri-operative system as the nurse performs the task of entering patient information for pre-operative assessment.

3.2. Complicated

Complicated tasks have components and relationships that are separated by time and space. The nature of the tasks is that cause and effect may be repeatable, and while the task has multiple interactions, they can all be proactively predicted. For example, collaborative care delivery involves teamwork in which clinicians work both

synchronously and asynchronously. The key is to understand the nature of the various interactions to ensure that HIT supports them appropriately while limiting unintended consequences. Clinical simulations can be used for systems analysis to understand how technology is used in complicated situations. Here, representative users can be asked to work with health information technology in realistic and repeatable scenarios in contexts. Data gathered using audio, video and computer screen recordings can be reviewed and analyzed to identify the unintended consequences. Video analysis can be further done to reveal the factors that contributed to the emergence of unintended consequences during the clinical simulations [14]. For example, a peri-operative nurse could be administering medication to a patient. In the process of administering the medications, s/he engages in several workarounds involving the system and the devices that are used to verify the patient's identity (i.e. bar code scanner, bar coded medication and the patients' bar coded identification bracelet). The nurse also needs to consult a perioperative information system to verify earlier information collected on the patient and to ensure there are no potential conflicts with the new medication. System understanding is brought to the situation as the nurse is interacting with several types of technology (including a medication administration system) and system components (e.g. team members or information from other perioperative areas).

3.3. Complex

Complex situations refer to instances where cause effect are not repeatable and will evolve and change over time. An examples is the handover process between units such as the operating room (OR) and post anesthesia care unit (PACU). Nurses described that in the previous paper based system the handover process had been mainly written with oral supplementation as needed. After implementing a perioperative HIT there was a large increase in the oral component of handovers. This change was attributed to two issues. One was the variation in surgery types where more complicated surgeries would lead to more complex handovers. The second issue was that some anesthetists described how the fast pace of handovers did not enable them time to accurately type a handover report, especially in complicated cases. Subsequently the handover process became more verbal with written supplementation as needed. Naturalistic observation can be used to better understand complex clinical situations such as the OR-PACU handover. Here, observations are directly made of the work environment where a nurse is performing patient care. Observations allow the researcher to identify the activities the nurse is performing and the interactions that she has with the technologies in her work environment to provide patient care. In these cases, there is a need to have trained observers note the interactions that take place. This work can also be done by video and audio recording of live interactions between a nurse and her colleagues in a given setting such as a patient care area or an operating room [16]. Given that complex tasks will evolve over time, observations must be done repeatedly to identify and understand the impact of such task evolution.

4. Discussion

This paper provides a framework that illustrates how CASs can be combined with HIT evaluation and systems analysis approaches for understanding the complex nature of HIT implementation. It addresses shortcomings in existing use of CASs in healthcare in

that we provide methodological details on how CASs can be used to study the tasks and issues. A key contribution from our framework is the distinction between the definition and understanding of tasks and issues. Definition helps categorize tasks & issues while understanding helps to understand them from both a HIT and complexity perspective. Some tasks are simple, others are more complicated and may span multiple agents or units, while others are complex and evolving and may not be apparent at first glance. It is essential that complex tasks are or probed in order to articulate the inner workings of the complexity as well as studying longitudinally given that complexity evolves over time. Limitations of our study are that the framework we developed is based on limited studies. Future work will evaluate our framework in other settings.

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