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Using conceptual work products of health care to design health IT

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ABSTRACT

This paper introduces a new, model-based design method for interactive health information technology (IT) systems. This method extends workflow models with models of conceptual work products. When the health care work being modeled is substantially cognitive, tacit, and complex in nature, graphical workflow models can become too complex to be useful to designers. Conceptual models complement and simplify workflows by providing an explicit specification for the information product they must produce. We illustrate how conceptual work products can be modeled using standard software modeling language, which allows them to provide fundamental requirements for what the workflow must accomplish and the information that a new system should provide. Developers can use these specifications to envision how health IT could enable an effective cognitive strategy as a workflow with precise information requirements. We illustrate the new method with a study conducted in an outpatient multiple sclerosis (MS) clinic. This study shows specifically how the different phases of the method can be carried out, how the method allows for iteration across phases, and how the method generated a health IT design for case management of MS that is efficient and easy to use.

1. Introduction

The great potential for health information technology (IT) to improve the quality and efficiency of clinical health care has yet to be realized [1]. Health IT applications have disrupted clinical workflow and decision-making in unpredictable and even dangerous ways [2,3]. Rigorous methods for designing and evaluating health IT lag behind its widespread deployment. Designing health IT means contending with the complexity of health care work. The additional complexity introduced by combining health care and interactive systems can disrupt care, discourage adoption, and undermine health IT's great potential value [1].

Model-based design techniques such as workflow and task analysis are increasingly recognized by the health IT community as important tools to create applications that are useful and usable [4–7]. However, graphical workflow models can become too complex and dense when the health care work being modeled is highly cognitive, tacit, and complex in nature. In this paper we present a model-based design method that complements procedural workflow models with conceptual models of the products of those workflows. By explicitly representing work products as conceptual models, health IT developers can (1) reveal essential information requirements for this important aspect of clinical care and (2) translate them more directly into software designs.

We illustrate this method with an example from a recent study conducted in an outpatient multiple sclerosis (MS) clinic within a tertiary federal hospital. The method includes formative evaluations to check the model's assumptions about technical feasibility, usability, and beneficial impact on workflow.

The case study we use to illustrate the method produced a new system we named Patient-Centered Case Management System (P-CMS).[1] Usability testing with experienced MS case managers indicates that the user interface of P-CMS makes it efficient and easy to perform key use cases of the workflow.

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[1] Note: all patient data shown in this paper are fictitious.

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Discrete event simulations of workflow predict that P-CMS would save more than 15% of the time required for case management in the clinic we studied. Technical feasibility analysis indicates P-CMS can be implemented as a web application without changing the code of the clinic's electronic health record (EHR).

1.1. Opportunities for model-based design

Model-based design is a promising approach for contending with the complexity IT has brought to clinical care. This turn toward model-based design is connected to our need for evidence that health IT will work as intended. In order to avoid introducing unintended negative consequences into health care work, we need to base health IT design decisions on evidence of how it will impact the way clinical care is actually done.

One of the greatest methodological challenges for health IT design is to document clinical care in a manner that allows us to understand how IT should be applied to improve it. Workflow modeling is an important form of graphically documenting care activities and their relationships [5,6,8]. But, when workflow models become too dense and complex their graphical representations lose much of their advantage. The goal of this paper is to demonstrate a new technique that complements workflow modeling with conceptual modeling. This method leads to evidence-based decisions for health IT that supports more efficient, effective workflows of clinical care. In the following sections we introduce procedural and conceptual approaches to modeling care, and then show how they can be used in combination to design health IT systems with a precise focus on information needs.

1.2. Procedural models

Task analysis and workflow modeling are two kinds of procedural modeling. Procedural models represent the sequence and contingencies of tasks performed in the service of work goals. In health IT task analysis is typically used to model the interactions between one human and one machine. Workflow modeling is used more to model collaboration among groups of people using multiple interactive systems.

Task analysis is a family of scientific methods used to "describe, and in some cases evaluate, the human–machine and human–human interactions in systems" [9]. Annett [10] surveyed the historical development of these methods, recognizing contributions from scholars in psychology and human factors, information theory, systems and control theory, artificial intelligence, knowledge engineering, and human–computer interaction. Various types of task analysis represent work in different ways to serve different aims. For example, cognitive task analysis draws on models of human problem solving from cognitive science [10], while hierarchical task analysis and Goals, Operators, Methods, and Selection Rules (GOMS) emphasize decomposing a problem into goals and subgoals [11]. The Task, User, Representation, and Function (TURF) framework by Zhang and Walji is the most developed task-analytic method for health IT [7]. TURF incorporates task analysis models in a unified framework for designing health IT systems that are measurably usable and useful.

In our approach, workflow is a type of business process modeling that can be used to describe or prescribe the work processes of groups of people and the relationships among their activities. The Object Management Group's standard for Business Process Modeling Notation is the most developed language for modeling work of groups that includes substantial, manually performed activities that are supported by computing [12]. Clinical care falls under this category of work.

Workflow models typically represent work at a higher level of abstraction than task analysis and cover a broader scope. For example, a GOMS model might represent a health care provider at her computer accessing data on patient's vital signs via the EHR. In contrast a workflow model might cover the broader process: the patient arrives at the clinic and checks in, a nurse rooms the patient and records vital signs in the EHR, and then a provider accesses the vital signs via the EHR and plans an order and enters it to the EHR.

Recent advances in workflow by Butler, et al. integrate the modeling of workflow tasks with modeling the information that is used and changed to perform those tasks [13,14]. Butler et al.'s MATH method also supports discrete event simulations that enable analysts to evaluate how better health IT will impact resource use and work efficiency [5].

1.3. Conceptual models

In contrast with procedural models, conceptual models do not specify activities or functions. Conceptual models are declarative. They specify the entities of a work domain, their relationships, and transitions in state in a manner that is independent of any given system to work on them.

Rummelhart and Norman [18] were among the first to report scientific evidence for the distinction between conceptual knowledge and procedural knowledge in human cognition. Zhang and Norman modeled the ontology of a conceptual problem to illustrate their theory of External Cognition [19]. A key principle of External Cognition is that there can be many different ways to represent a given conceptual model that are logically equivalent. Despite their logical equivalence these representations can have very different effects on the cognitive strategy they induce. Butler and Zhang [13] and Zhang and Walji [7] have extended this theory into a method for the design of interactive systems.

Conceptual models are well established for domain modeling in software design. Jacobson's use-case method was among the first to popularize their application in combination with procedural models of work [15]. Related research includes Dowell and Long [16] who held that an object of work should be modeled as external to the work system being designed to produce it. Dowell [16] applied their approach in an elegant solution to the cognitive design problem of air traffic management. Rasmussen's method for cognitive work analysis requires a high-level functional analysis [17] that conceptual models can satisfy.

1.4. Conceptual work products in health care and health IT design

Conceptual work products are a part of domain models that have been under recognized in popular design methods. They are the entities that conceptual work activities operate on to transform them to their goal (product) state. Our workflow studies have shown conceptual work products have fundamental importance in clinical care as diagnoses, plans for contacting patients, treatment plans, and schedules for using equipment and facilities. These are key information objects of health care work but they have no manifestation in the material world until they are acted on, making them vague and difficult to define clearly.

Conceptual work poses problems for health IT support. In comparison to tangible work done in the physical world – work that is overtly observable – the nature of conceptual work is not as evident. An additional complication is that the knowledge about conceptual work may be distributed over multiple human and machine resources. Information systems are actually carried out not only by computers but also by the manual and cognitive activity of clinicians. As they interact they must transform the conceptual work product into its goal state or the system will fail. A key risk of failure arises if developers cannot specify the product of conceptual work that their system is supposed to accomplish.