Cognitive-Engineering Approaches to Assessing the Usability of Healthcare Information Technologies

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Abstract

We have witnessed a significant growth of health information technologies (HIT) across healthcare sectors. It is recognized that usability problems represent an impediment to the productive use of HIT. The tutorial will provide participants with knowledge and skills pertaining to the use of cognitive-engineering methods in the design and evaluation of health information technologies. The first section of the tutorial will introduce concepts from cognitive engineering and distributed cognition. The focus will be on their application to human-computer interaction and health information technologies. We will liberally draw on problems in real-world clinical and patient-centered settings, using video vignettes, to illustrate challenges that confront users. Usability evaluation methods will form the core of the tutorial. The session will demonstrate usability inspection, usability testing and clinical simulation methods as well as techniques to evaluate the efficacy of graphical representations and visualizations. We will also briefly introduce methods of computational ethnography. The final part of the tutorial will focus on ways to convert evaluation results into concrete design strategies as well as to providing effective feedback from both participatory and user centered design. The central learning objectives are to provide attendees with the prerequisite skills to carry out cognitive usability evaluations and to facilitate the ability to make informed design and technology selection choices. Approximately 50\% of the tutorial will be devoted to hands-on activities in which participants will engage in a multi-faceted evaluation process and interface-design prototyping.

Keywords:
Health information technologies; Cognitive Science; Usability evaluation; Human computer interaction; Computational Ethnography, User-centered design.

Tutorial Description

Health information technologies (HIT) have permeated all facets of the health care arena. However, poor system usability has been increasingly associated with failure of information technologies in healthcare and compromised patient safety (1). Usability can be defined as a measure of how effective, efficient, safe, easy to learn and enjoyable it is to use a system. Successful design, implementation and deployment of healthcare information systems is dependent on careful consideration of usability. Research and methods from a cognitive-engineering perspective can be combined with software engineering approaches and contribute to the iterative design process. Improved understanding of the cognitive capabilities and limitation of users of health information systems will be essential in developing healthcare technologies that are both usable and useful (2).

The tutorial will provide attendees with a set of knowledge and skills pertaining to the use of cognitive-engineering methods in the design and evaluation of health information technologies. Users of health systems differ significantly in their computer acumen, literacy and their physical capabilities. In particular, we will focus on describing methods that can be applied to improve the quality and safety of health information systems in their organizations. The tutorial will help health informatics professionals who are involved in the process of designing, developing, testing, procuring or implementing systems in hospital, community and clinic settings. Participants will work through practical examples of how to apply a cognitive approach to usability engineering using examples from evaluation of a range of technologies. A variety of methods from traditional to cutting edge will be presented as well as practical approaches to cognitive-engineering in healthcare.

Topical Outline

The tutorial will be divided into three broad sections. First, we will address the theoretical and practical foundations for cognitive-engineering and distributed cognition approaches to different user populations, including health professionals and patients. Second, we will present methods for the evaluation of both clinical information systems and patient-centered informatics interventions including; the cognitive walkthrough, heuristic evaluation and video-analytic field usability testing. Low-cost rapid methods for deploying usability studies in real healthcare contexts and settings will be described. The third section will be devoted to user-centered design and strategies for converting evaluation results into concrete interventions to improve existing systems. Approximately 50\% of the tutorial will be devoted to hands-on activities in which participants will engage in a multi-faceted evaluation process and interface-design prototyping. The tutorial will draw on several studies including 1) a cognitive assessment of a large-scale home telemedicine project (3) and 2) an integrated approach to evaluation of a health information system in “near live” use that involved a layered approach to evaluation (4). The methods described in this tutorial will be of interest to anyone interested in innovative methods for designing and evaluating health information technologies. This session is grounded in a cognitive engineering (CE) (5) and distributed cognition framework (DCog) (6), which are interdisciplinary approaches to the development of principles, methods and tools to assess and guide the design of computerized systems to support human performance. In supporting performance, the focus is on cognitive functions such as attention, perception, memory, comprehension, problem solving, and decision-making. The approach is centrally concerned with the analysis of cognitive tasks and the processing constraints imposed by the human cognitive system. The focus is equally on 1) dimensions of the system that facilitate and impede productive use of systems and 2) user skills and competencies pertaining to system mastery (7). DCog represents a shift in the study of cognition from an exclusive focus on the mind of the individual to being stretched across groups, material artifacts and cultures.
paradigm has gained substantial currency in HCI research. Distributed cognition has two focal points of inquiry, one that emphasizes the social and collaborative nature of cognition (e.g., attending physicians, residents and nurses in jointly contributing to a decision process), and one that characterizes the mediating effects of technology (e.g., EHRs, mobile devices apps) or other artifacts on cognition.

**Tutorial Structure**

1) **Theoretical Foundation and Practical Grounding**

**Core Concepts:** The first topic in the tutorial will introduce core theoretical concepts from cognitive engineering and distributed cognition. The focus will be on their application and relevance to human-computer interaction and health information technologies. We will introduce basic concepts in cognitive-engineering as applied to HCI in relation to attention and memory, cognitive load, mental models, workflow, and theory of action. Distributed cognition concepts include technology and socially-mediated cognition, distributed resources and intelligent use of space. **Populations and Settings:** Patient self-management initiatives are increasingly relying on the use of technologies to facilitate the process of care in the home. These technologies range from medical devices such as glucose monitors to comprehensive computer-mediated telemedicine systems or personal fitness devices (e.g., the Fitbit) that provide interactive support as well as web access. However, these systems present formidable challenges to many patients, especially seniors, novice computer users and those who are less literate (3). Patients are distinct population(s) of users with unique characteristics (e.g., as it relates to aging) and requirements. Clinical settings, technologies and personnel vary greatly as well. For example, the same EHR document may be viewed by residents, attending physicians, nurses, pharmacists and social workers. Each type of clinician has distinct roles, idiosyncratic needs, as well as variable experience and knowledge. Clinical settings also vary immensely from ambulatory settings to high velocity intensive care units in large tertiary hospitals. It is important to appreciate their dimensions of difference in planning any user-centered design or usability evaluation studies. The concepts will be illustrated with case studies and the liberal use of video vignettes.

2) **Usability Evaluation Methods**

The demonstration of methods will form the core of the tutorial. We will employ case studies to demonstrate each method. In addition, about 50% of the time in this section will be devoted to hands on exercises, discussion and related activities. a) **Usability Inspection:** The Cognitive Walkthrough (CW) and Heuristic Evaluation (HE). The CW is a task-analytic usability inspection method which has been applied to the study the usability and learnability of several medical information technologies (8). The purpose of a CW is to evaluate the cognitive processes of users performing a task. The method involves identifying sequences of actions and goals needed to accomplish a given task. The specific aims of the CW procedure are to determine whether the user’s background knowledge and the cues generated by the interface are likely to be sufficient to produce the correct goal-action sequence required to perform a task. The method is intended to identify potential usability problems that may impede the successful completion of a task. The CW provides us with substantial insight into the cognitive demands of a task. For example, tasks that require the user to execute lengthy sequences of actions or require movement between different screens make heavier demands on a user’s working memory. HE assesses a user interface based on a set of usability principles regarding the quality of interface design (9). The heuristic principles typically include system status visibility, consistency and standards, and error prevention. Conducting a HE involves going through an interface to identify potential violations to a set of usability principles. These violations may involve a variety of interface elements such as windows, menu items and links. After evaluating the heuristics, the violations are rated according to severity. HE is one of the most widely used methods, has a broad range of application and can be learned in a short period of time.

**Usability testing and Clinical Simulation:** Usability testing refers to studies that involve observation of representative users of systems carrying out representative tasks using the system under study. Usability testing can be extended to include conducting the studies in representative environments (i.e. “In-situ” in real or near-real clinical or home environments). Such an approach to testing has been shown to be both low-cost (as it does not require a fixed usability laboratory) and can lead to the collection of high fidelity data (i.e., representative of real use) (10). In this tutorial, the economic benefits of the low-cost rapid usability testing approach will be demonstrated. The extension of usability testing to include real or realistic settings has been termed “clinical simulation”. In this section of the tutorial an example will be given of use of usability testing, followed by a round of clinical simulation in order to ensure both system usability and safety prior to widespread deployment of the technology. Examples from both the study of applications targeted to health professionals and patients in field studies will be presented. We will also demonstrate the use of a video capture and video analysis tool, Morae™. It provides a video of screen activity and logs a wide range of events and system interactions including lapsed time, mouse clicks, screen transitions and web-page changes. These events can be transformed into a series of quantitative variables that can provide benchmark measures of efficiency.

**Representational and Visualization:** External representations such as images, graphs, icons, and text are vital means of communication. The representational effect is a well-documented phenomenon in which different representations of a common abstract structure can have a significant effect on learning, reasoning and decision making (11). Different forms of visual representations such as graphs, tables and lists can dramatically affect one’s comprehension even when they present the exact same information. Representational analysis is a method for characterizing the properties of nonnumeric and numeric data representations and their cognitive effects. This part of the tutorial will focus on making design choices that pertain to the efficacy of data representation types for a given task and user population. This method is well suited for developing and selecting visualizations (e.g., graphs) for particular clinical purposes (e.g., reviewing trends in lab tests) and for promoting health-related understanding in low literacy/numeracy patients.

**Computational ethnography** is an emerging family of cutting-edge methods for studying human performance in technology-mediated healthcare work settings (12). These methods employ unobtrusive automated means for collecting data that reflect users’ interactions with systems in real-world settings. Computer logs of EHRs generate a rich array of data and facilitate the understanding of different dimensions of interaction including time on task, documentation patterns and information accessed by role (e.g., residents, nurses). Logfile analysis can be a powerful tool for reconstructing the clinical
workflow process in a given healthcare facility. In addition, sensor-based technologies such as RFID (radio-frequency identification) can capture movement between clinicians, patients and health technologies in a particular setting. It can answer questions pertaining to how the physical layout of a clinic constrains the coordination of patient care. The integration of both quantitative data from logfile analysis and qualitative data (collected from online usability questionnaires) will be described in the context of an evaluation tool known as the Virtual Usability Laboratory (VUlab) (13).

**User-Centered Design and Participant Training**

An objective of this tutorial is to articulate a comprehensive evaluation framework for enabling clinicians, patients and health consumers to more effectively leverage HIT in the context of healthcare. Implicit in this strategy is the need to continuously evaluate and improve existing systems. This section will focus on ways to convert evaluation results into concrete strategies. Ways of providing effective feedback from cognitive engineering approaches into both participatory and user centered design will be discussed. Issues around organizing, summarizing and presenting results to design teams will also be discussed. In addition, feedback from studies into improving training and support will be described. These strategies include targeted training and web-based tutorials.

**Learning Objectives**

The goals of the tutorial are: 1) to characterize the design and evaluation challenges in health information technologies; 2) to provide attendees with the prerequisite skills to carry out cognitive usability evaluations including usability inspection and video-analytic usability testing; 3) to explain and illustrate concepts and methods of user-centered design; 4) to communicate a comprehensive set of design and evaluation principles and methods such that participants can make more informed decisions concerning the development, selection, purchase and implementation of health information technologies.

**Expected Attendees**

Anyone involved or interested in the design, evaluation and selection of health information technologies should attend. There are no prerequisites.

**Dr. David Kaufman** is an Associate Professor and Academic Program Director in Biomedical Informatics at Arizona State University. Dr. Kaufman has worked in the area of human-computer interaction for the last 20 years, evaluating a wide range of health information technologies developed for clinicians, patients and health consumers. He has published several papers related to applying video-analytic cognitive scientific methods to the study of the productive use of health information technologies and devices. He has been involved in several HCI projects pertaining to the evaluation of electronic health records, computer-provider order entry systems and a large-scale telemedicine system for patients with diabetes. **Dr. Andre Kushniruk** is Director and Professor at the School of Health Information Science at the University of Victoria in Canada. Dr. Kushniruk conducts research in a number of areas including usability engineering, electronic health records, evaluation of the effects of information technology, human-computer interaction in healthcare and other domains. His work is known internationally and he has advised on variety of national and international committees and projects. He focuses on developing new methods for the evaluation of health information technology and studying human-computer interaction in healthcare. Drs. Kaufman and Kushniruk have worked in the area of HCI and healthcare for more than 20 years. They have conducted numerous tutorials and been actively involved in national and international educational activities pertaining to this field of study and practice.

**References**


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