

## Guest Editorial

### **Human-Centered Computing in Health Information Systems – Part 1: Analysis and Design**

Guest Editor: Jiajie Zhang

School of Health Information Sciences  
University of Texas Health Science Center at Houston  
Houston, Texas, USA  
Jiajie.Zhang@uth.tmc.edu

A large number of health information system projects fail. Most of these failures are not due to flawed technology, but rather due to the lack of systematic considerations of human and other non-technology issues in the design and implementation processes [1-8]. In other words, designing and implementing a health information system is not so much an IT project as a human project about human-centered computing such as usability, workflow, organizational change, medical error, and process reengineering. In other industries such as aviation, nuclear power plants, automobiles, and consumer software and electronics, human-centered design is a routine practice. In healthcare, however, the culture is still to train people to adapt to poorly designed technology, rather than to design technology to fit people's characteristics. Human-centered methods and techniques specifically developed for healthcare domains are necessary for the successful development of health information systems that increase efficiency and productivity, increase ease of use and ease of learning, increase user adoption, retention, and satisfaction, and decrease medical errors, decrease development time and cost, and decrease support and training cost.

Human-centered computing covers more than traditional usability engineering, human-computer interaction, and human factors, which are primarily concerned with user interfaces [9-11]. As described in Zhang et al. [12], human-centered computing is based on four types of analyses: user, functional, representational, and task analyses. User analysis is the process of identifying the characteristics of existing and potential users, such as expertise, knowledge, skills, education levels, cognitive capacities and limitations, perceptual variations, ages, cultural background, personalities, times available for learning and training, etc. User analysis can help us design systems that have the right knowledge and information structures that match those of the users. Functional analysis is the process of identifying a system's abstract structures that are independent of implementations. Its product is the ontology of a given work domain. This ontology is an explicit, abstract, implementation-independent description of the work domain. It includes (a) objects and their attributes, (b) resources and their types, (c) relations among entities and constraints on relations, (c) operations on single or multiple objects, transformations, relations, and constraints, and (d) workflow structures [13]. Representational analysis is the process of identifying an appropriate information display format for a given task performed by a specific type of users such that the interaction between users and systems is in a direct interaction mode [14-15]. With direct interaction

interfaces, users can directly, completely, and efficiently engage in the primary tasks they intend to perform, not the housekeeping interface tasks that are barriers between users and systems. Traditional user interface design is mostly at the level of representational analysis. Task analysis is the process of identifying the procedures and actions to be carried out and the information to be processed to achieve task goals by using specific representations [16-18]. For the same task goal, different representations can lead to very different sets of task steps that require different types of information. Task analysis can generate estimates of relative task difficulties and complexities and help understand the workflows of tasks.

Human-centered computing is also a process that includes work domain analysis, design, and evaluation as three major steps. In order to develop a human-centered product for a work domain, we first need to understand the nature of the work. After the work domain analysis, we need to design and implement the product. Then the product has to be evaluated using human-centered criteria.

Two special issues are produced to bring together original research and methodology papers that focus on human-centered computing in health information systems. Issue 1, the current issue, focuses on the domain analysis and design aspects of human-centered computing. Issue 2 will focus on the evaluation aspect. Health information systems in these two special issues include, but are not limited to, electronic health records (EHR), decision support systems, medical devices, telemedicine systems, PDAs, communication systems, public health information systems, cognitive artifacts, and others.

The following is an introduction to the papers in Issue 1—Analysis and Design.

The first paper by Rinkus et al [19] is a direct reflection of the human-centered computing defined above. It applies the four types of analyses and a more elaborate Product Design Lifecycle in the analysis, design, and evaluation of a knowledge management system for a distributed work environment that is composed of multiple teams of people distributed across space and time and interacting with multiple types of artifacts (both advanced computing devices and traditional artifacts). The domain is the Biomedical Engineer and Flight Surgeon Console in the Mission Control Center at NASA Johnson Space Center. The authors analyzed this complex system, identified its problems, generated systems requirements, and provided specifications of a replacement prototype for effective organizational memory and knowledge management. They demonstrated the value provided by their human-centered approach and described the unique properties, structures, and processes discovered using this methodology and how they contributed in the design of the prototype. This paper involves all four types of analyses of users, functions, representations, and tasks.

The next two papers focus on functional analysis. The paper by Nemeth et al. [20] introduces an emerging paradigm called cognitive work analysis [21] and its applications in the design of healthcare IT. There is little evidence that the use of IT will have sustainable positive effects in improving patient safety, despite that much of government funding has been directed to support the production of such new IT systems. In their opinion, in order to get the desired effects of new IT in healthcare, it is essential to understand the cognitive work performed by the practitioners. They used two examples, infusion pumps and operating room schedules, to demonstrate the procedures and outcomes of cognitive work analysis. Nemeth et al. also introduced the distributed

cognition framework [22-23] and the properties of cognitive artifacts [24], which are the focus of the next paper by Xiao [25]. According to Xiao, healthcare is delivered in the context of a highly structured physical environment, with much effort on physical and spatial arrangement and re-arrangement of workers, patients, and materials. This article reviewed field studies in healthcare and other domains on the role of artifacts in collaborative work and demonstrated how artifacts are used and exploited to facilitate collaborative work in the scheduling of operating rooms. The author suggests that new technology should support the functions provided by physical artifacts that are replaced or disrupted by new technology and that new technology needs to be sensitive to the distributed nature of cognitive work by healthcare workers.

The next two papers focus on task analysis. Malhotra et al. [26] conducted semi-structured interviews of healthcare providers, biomedical engineers, and administrators who were involved with various degrees in the use, maintenance, or purchasing of infusion pumps. The interviews were centered on three scenarios of medical errors with infusion pumps and the participants were asked to assess, rank, and explain the medical errors. The results from this study were used to develop a patient-centered methodology for designing medical devices. The paper by Rose et al. [27] describes a study that used task analysis and focus group to discover usability problems of an EHR module and to generate redesigns that eliminate the discovered usability problems. Usability is a major factor for the successful adoption of any EHR systems. This paper is one of very few published studies that explicitly examine the usability problems of EHR.

The next paper by Samaras and Horst [28] focuses on design life cycles. The primary objective is to reconsider human-centered design of health information systems from a systems engineering perspective. Systems engineering is a structured, systematic approach to system risk reduction over the full lifetime of the system (from cradle to grave). It is particularly important for new product development of complex systems. The authors reviewed various models of design life cycles and analyzed two medical error cases involving radiation overdoses. From these results the authors argue that the various models of design life cycles in usability engineering are subset of the classical systems engineering method and thus introducing the core components of systems engineering back to design life cycles will increase the reliability, compliance, and safety of health information systems.

The last paper by Johnson et al. [29] is the methodology review paper for this special issue. Numerous health information systems are designed without consideration of user-centered design guidelines. This often results in user dissatisfaction and abandonment. In order to salvage the systems that are designed without usability considerations, the authors combined different methods from the area of computer science, cognitive science, psychology, and human-computer interaction to formulate a framework for guiding the redesign process. The authors first provided a review of the different methods involved in the design process and presented a lifecycle of their own redesign approach. The authors then applied the new method to the redesign of a software application that tracks genetic history of patient families, compared the new design with the old one, and demonstrated the improvement of usability of the new design.

This is the first of the two special issues. It focuses on the domain analysis and product design aspects of human-centered computing. The next issue will be dedicated to papers centered on the evaluation aspect of human-centered computing.

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