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A cognitive systems engineering design approach to improve the usability of electronic order forms for medical consultation

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ABSTRACT

Background: During medical referrals, communication barriers between referring and consulting outpatient clinics delay patients' access to health care. One notable opportunity for reducing these barriers is improved usefulness and usability of electronic medical consultation order forms. The cognitive systems engineering (CSE) design approach focuses on supporting humans in managing cognitive complexity in sociotechnical systems. Cognitive complexity includes communication, decision-making, problem solving, and planning.
Objective: The objective of this research was to implement a CSE design approach to develop a template that supports the cognitive needs of referring clinicians and improves referral communication.
Methods: We conducted interviews and observations with primary care providers and specialists at two major tertiary, urban medical facilities. Using qualitative analysis, we identified cognitive requirements and design guidelines. Next, we designed user interface (UI) prototypes and compared their usability with that of a currently implemented UI at a major Midwestern medical facility.
Results: Physicians' cognitive challenges were summarized in four cognitive requirements and 13 design guidelines. As a result, two UI prototypes were developed to support order template search and completion. To compare UIs, 30 clinicians (referrers) participated in a consultation ordering simulation complemented with the think-aloud elicitation method. Oral comments about the UIs were coded for both content and valence (i.e., positive, neutral, or negative). Across 619 comments, the odds ratio for the UI prototype to elicit higher-valenced comments than the implemented UI was 13.5 (95% CI = [9.2, 19.8]), $p < .001$.
Conclusion: This study reinforced the significance of applying a CSE design approach to inform the design of health information technology. In addition, knowledge elicitation methods enabled identification of physicians' cognitive requirements and challenges when completing electronic medical consultation orders. The resultant knowledge was used to derive design guidelines and UI prototypes that were more useful and usable for referring physicians. Our results support the implementation of a CSE design approach for electronic medical consultation orders.

1. Introduction

More than a third of patients in the United States are referred to a specialist each year, and more than half of outpatient visits are with specialists [29]. Although consultation is a core clinical process, it is a long-standing source of frustration for clinicians, due to communication breakdowns in the process. Some of these breakdowns include the consultation requests being directed to the wrong specialty or consulting service, delayed information from either the referring or consulting clinician, unclear information from the referrer, insufficient

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information in the consultation request, patients not attending the consultation, and the priority of requests not being communicated to the consultant [17,46]. Managing consultations requires coordination and avoiding communication breakdowns among referrers, consultants, ancillary staff, and patients.

In many health care systems, when clinicians decide to send their patients to consultants, they generate referrals by ordering consultations in electronic health record (EHR) systems. Referral-related communication between clinicians is often inadequate (e.g., [9]. As the first step in referral communication, the consultation order is also the first point of communication breakdowns. Both referrers and consultants make errors of omission that could be prevented by a well-designed consultation order form. For example, referrers might not communicate necessary information, like a clinical question, the reason for consultation, or level of urgency [13]. On the other hand, consultants might not communicate the recommendations or findings. In some cases, roles of referrers or consultants in clinical co-management are unclear [16,50]. Therefore, issues with the consultation process can be described as sociotechnical [5,49,57].

Technological support for communication and coordination plays a key role, but EHR systems also contribute to unexpected barriers in the consultation process. Since 2009, spurred by government incentives to promote patient safety and communication among clinicians, EHRs have been increasingly adopted and are now used widely [1,8]. Despite increased use, EHRs have not yet improved communication adequately; both referrers and consultants agree that the current approach to referral and consultation is flawed, with poor EHR usability as a contributing factor [29,39]. Across public and private health care systems, studies have noted information-transfer challenges, fragmented care, and delayed access to specialty care [15,23,39,46,58]. Therefore, the implementation of a design approach capable of addressing the complexities of coordination, communication, and decision-making across clinical teams, information systems, and health care facilities is warranted [53].

Cognitive systems engineering (CSE) is an approach to the design of technology, training, and processes intended to manage cognitive complexity in sociotechnical systems, such as a medical center [12,21,31,42,51]. Cognitive complexity includes activities such as identifying, judging, attending, perceiving, remembering, reasoning, deciding, problem-solving, and planning [31,36], all of which referring and consulting clinicians must manage in the consultation process. Although cognition, by definition, refers to an individual's mental process, from a systems view, it is valuable to consider the concept of joint cognitive systems focusing on how humans and technology interact to perform complex work (e.g., primary care physician interacting with a computerized consultation template; [22,56]).

CSE advocates for methods aimed at understanding the world of work with an emphasis on cognitive challenges [33,42]; however, specific methods are not prescribed. Rather, methods are tailored to each project depending on project goals and resource constraints. CSE methods are often used with participatory design and ecological interface design. Examples of the application of CSE include strategies to inform models of workflow [53], work products [6], and cognition [4]. For this project, we combined documentation reviews to identify the intent of the electronic consultation order, interviews to obtain first-person perspectives, and observations to explore cognitive work as it occurs across humans and technology. Previous studies of consultations focused on rates and types of failure [13,17,46,58] or on strategies for improving consultations processes and clinical practice [15,47]. However, this study focused on creating a foundational description of complex cognitive activities, contextual elements that increase difficulty, and how information flows across humans and technologies throughout the consultation process [35].

The objective for this research was to implement a CSE design approach to develop a template that supports the cognitive needs of referring clinicians in appropriately requesting consultations, which is the first step in the consultation process. CSE methods have not been applied to the design of consultation user interfaces (UIs). With an interdisciplinary team, which included physicians, human factors engineers, informaticians, and graphic designers, we followed a CSE approach to deriving cognitive requirements, translating them into design of a new prototypes for consultation, and evaluating the prototypes. As predicted by paradigms of cognitive fit and task-technology fit, when a UI is aligned with users' mental representations and external workflow, usability—specifically, task performance—improves [18,54]. This study details one portion of a larger project to identify barriers and facilitators to effective consultations and deliver recommendations for mitigating barriers. Within the overarching goal, this study demonstrates the use of CSE in early stages of an adapted, iterative, interdisciplinary design process that supported shorter interview sessions to align with physicians' busy work schedules. To achieve our objective, we outlined the following aims: (1) identify cognitive requirements, (2) translate requirements to design guidelines, (3) design UI prototypes, and (4) evaluate usability impact. Compared with the currently implemented UI, we predicted that the prototypes would elicit more positive comments about its usability. Based on our review, this is the first study to apply CSE design methods to electronic consultation orders to improve decision and communication support.

2. Cognitive systems engineering design approach

Fig. 1 illustrates the phases of this study. We chose CSE methods that overlap with other design frameworks to illustrate the potential of knowledge/skill transfer and increase likelihood of adoption for future designs. In the following section, our CSE design approach is discussed. Subsequently, we present our evaluation methods. We conducted a scenario-based simulation that compared the usability of the UI prototype with the usability of a currently implemented UI. In addition, we incorporated measures of clinicians' reactions to estimate impact of the designs derived from the CSE approach. Approval for the study was obtained from the U.S. Department of Veterans Affairs Central Institutional Review Board (Protocol 13–53).

2.1. Interviews and observations

2.1.1. Participants

Participants were clinicians and supporting staff at two medical centers and associated community-based outpatient clinics in the

Fig. 1. Overview of the phases of decision-centered design. Adapted from Working Minds: A Practitioner's Guide to Cognitive Task Analysis (p. 181), by B. Crandall, G. A. Klein, & R. R. Hoffman, 2006, Cambridge, MA: MIT Press. Adapted with permission.