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Formative evaluation of a patient-specific clinical knowledge summarization tool

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ABSTRACT

Objective: To iteratively design a prototype of a computerized clinical knowledge summarization (CKS) tool aimed at helping clinicians finding answers to their clinical questions; and to conduct a formative assessment of the usability, usefulness, efficiency, and impact of the CKS prototype on physicians' *perceived decision quality* compared with standard search of UpToDate and PubMed.
Materials and methods: Mixed-methods observations of the interactions of 10 physicians with the CKS prototype vs. standard search in an effort to solve clinical problems posed as case vignettes.
Results: The CKS tool automatically summarizes patient-specific and actionable clinical recommendations from PubMed (high quality randomized controlled trials and systematic reviews) and UpToDate. Two thirds of the study participants completed 15 out of 17 usability tasks. The median time to task completion was less than 10 s for 12 of the 17 tasks. The difference in search time between the CKS and standard search was not significant (median = 4.9 vs. 4.5 min). Physician's *perceived decision quality* was significantly higher with the CKS than with manual search (mean = 16.6 vs. 14.4; $p = 0.036$).
Conclusions: The CKS prototype was well-accepted by physicians both in terms of usability and usefulness. Physicians perceived better decision quality with the CKS prototype compared to standard search of PubMed and UpToDate within a similar search time. Due to the formative nature of this study and a small sample size, conclusions regarding efficiency and efficacy are exploratory.

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1. Introduction

Clinicians often raise clinical questions in the course of patient care and are unable to find answers to a large percentage of these questions. A systematic review of 21 studies has shown that clinicians raised on average one clinical question out of every two patients seen and that over half of these questions were left unanswered [1]. Recent advances in online clinical knowledge resources offer an opportunity to address this problem. Studies have shown that, when used, these resources are able to answer over 90% of clinicians' questions, improving clinicians' performance and patient outcomes [2–12].

Despite increased clinician adoption of online resources, recent studies still show a stable picture, with most questions continuing to be left unanswered [1]. It appears that significant barriers still challenge the use of online resources to support clinical decisions [1]. One possibility is that clinicians often cannot process the large amount of potentially relevant information available within the timeframe of a typical patient care setting. Several solutions have been designed to address this problem, such as manual curation and synthesis of the primary literature (e.g., systematic reviews, clinical guidelines, evidence summaries), context-specific links to relevant evidence resources within electronic health record (EHR) systems [10], and clinical question answering systems [13]. Although some of these solutions have shown to be effective, there are still opportunities for further improvement [10,14,15].

In the present research we explore automatic text summarization and information visualization techniques to design a clinical decision support (CDS) tool called Clinical Knowledge Summary (CKS). Given the tight timelines and competing demands on the

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attention of providers, designing a system for knowledge summarization is extremely important. Currently, allotted time to see patients has been decreasing with more intense pressure to expand revenues. As a result, primary care clinicians in outpatient care may only have less than a few minutes to pursue questions. The CKS retrieves and summarizes patient-specific, actionable recommendations from PubMed citations and UpToDate articles. The summarization output is presented to users in a highly interactive display. In the present study we report the results of a formative, mixed-methods assessment of a high-fidelity prototype of the CKS. The study aimed to assess the usability of the CKS, obtain insights to guide CKS design, and assess the CKS impact on physicians ability to solve questions in case vignettes.

2. Methods

The study consisted of mixed-methods observations of physician interactions with the CKS prototype in an effort to solve clinical problems posed as case vignettes. The study addressed the following research questions: (1) To what degree are the CKS features *easy to use* and *useful*; (2) how *efficient* are CKS searches as compared to manual searches; and (3) how do CKS searches differ from manual searches in terms of clinician's *perceived decision quality*?

2.1. CKS tool design

The CKS design was guided by the following set of principles derived from Information Foraging theory [16]: (i) maximize *information scent* (i.e., cues to help identify relevant information); (ii) facilitate the cost-benefit assessment of *information-seeking effort* by providing measures of the amount of information available and enabling quick information scanning; and (iii) enable *information patch* enrichment (i.e., features that allow users to increase the concentration of relevant content). We also followed Shneiderman's visual information seeking principles: (i) first, information overview from each source; (ii) followed by zoom and filtering; and (iii) then on-demand access to details [17].

The CKS was designed in rapid iterative cycles guided by feedback and insights obtained from informal user interactions with prototypes. In the early cycles, we experimented with multiple alternate "low-fidelity" prototypes in the form of diagrams and screen mockups. The low-fidelity prototypes progressively evolved towards "high-fidelity" prototypes implemented in HTML and JavaScript until a more stable design was achieved for the formative evaluation. During the formative evaluation, the CKS tool went through one additional version to improve usability after exposure to the first set of study participants. Fig. 1 depicts the method employed in each CKS design stage.

2.2. CKS software architecture

The CKS architecture consists of two independent processes (Fig. 2) built over open source and publicly available components. To enable real-time performance for the CKS, we pre-process text sources through a text summarization pipeline and store the results in a relational database (Fig. 2A). High quality clinical studies are identified from PubMed using a machine learning classifier developed by Kilicoglu et al. (Fig. 2A, Step A.1) [18]. PubMed abstracts and UpToDate articles are processed by a classifier that uses concepts, semantic predications, and deontic terms as predictors of sentences that provide clinically actionable recommendations (Step A.2) [19,20]. The output from Steps A.1 and A.2 is stored in a relational database in the form of sentence-level metadata (Step A.3).

At real-time, the CKS application, which was developed in HTML and JavaScript, starts the process by sending a Hypertext Transfer Protocol (HTTP) request to OpenInfobutton [21], a Java-based, Infobutton Manager Web service compliant with the Health Level Seven (HL7) Infobutton Standard (Fig. 2B, Step B.1) [22]. The request includes contextual information about the patient, the user, and the care setting.

The Infobutton Manager uses this information to retrieve relevant articles from PubMed and UpToDate using PubMed's native search engine and UpToDate's HL7 Infobutton Web service (Step B.2). Relevant documents are retrieved in JSON format, also compliant with the HL7 Infobutton Standard (Step B.3). For the retrieved articles, the Infobutton Manager uses standard query language (SQL) to retrieve a subset of high quality articles along with clinically actionable sentences from the pre-processed summarization database (Step B.4). These recommendations along with links to the original source are aggregated to produce an output in JSON format compliant with the HL7 Infobutton Standard (Step B.5). The CKS user interface parses the JSON output and presents the clinically actionable statements extracted from UpToDate articles and PubMed abstracts. Features of the CKS user interface are described in Section 3. Details of the CKS architecture, the HL7 Infobutton Standard, and the summarization algorithms are described elsewhere [18–21,23–25].

2.3. Study settings

Formative evaluation sessions were conducted at the University of Utah and the University of North Carolina Chapel Hill. Sessions were conducted onsite and remotely via online conference meeting. Participants accessed an instance of the CKS that was hosted in the cloud.

2.4. Participants

Users in the iterative design stage included clinician collaborators and members of the research team. For the formative evaluation, we recruited a sample of 10 physicians who had not participated in the iterative design stage and had no previous exposure to the tool. We sought a purposive sample of physicians with various specialties and a wide range of clinical experience. The goal was to expose the tool to a diverse group of users.

2.5. Case vignettes

We adapted six case vignettes that were developed and validated in previous studies [26–31]. All vignettes were focused on patient treatment and covered a range of medical problems in different areas, such as diabetes mellitus, atrial fibrillation, and depression. To increase the complexity of the cases, the problem posed in the vignettes could be resolved in multiple ways. The goal was to stimulate physicians to consider multiple treatment alternatives in their information-seeking sessions.

2.6. Procedure

Sessions started with a brief introduction and description of the study. Participants interacted with a brief, 2-slide tutorial describing the CKS tool. Next, participants were assigned to three case vignettes, each of which was used in a specific segment of the study session.

2.6.1. CKS usability

The first segment was focused on CKS usability and allowed participants to familiarize themselves with the tool. Participants were asked to complete 17 tasks within the CKS (Table 1), such as finding a relevant randomized controlled trial or systematic review, finding a study sample size and funding source, and linking to the original source of a particular sentence. The tasks were designed to cover all