Understanding the nature of information seeking behavior in critical care: Implications for the design of health information technology

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ABSTRACT

Objective: Information in critical care environments is distributed across multiple sources, such as paper charts, electronic records, and support personnel. For decision-making tasks, physicians have to seek, gather, filter and organize information from various sources in a timely manner. The objective of this research is to characterize the nature of physicians' information seeking process, and the content and structure of clinical information retrieved during this process.

Method: Eight medical intensive care unit physicians provided a verbal think-aloud as they performed a clinical diagnosis task. Verbal descriptions of physicians' activities, sources of information they used, time spent on each information source, and interactions with other clinicians were captured for analysis. The data were analyzed using qualitative and quantitative approaches.

Results: We found that the information seeking process was exploratory and iterative and driven by the contextual organization of information. While there was no significant differences between the overall time spent paper or electronic records, there was marginally greater relative information gain (i.e., more unique information retrieved per unit time) from electronic records ($t(6) = 1.89$, $p = 0.1$). Additionally, information retrieved from electronic records was at a higher level (i.e., observations and findings) in the knowledge structure than paper records, reflecting differences in the nature of knowledge utilization across resources.

Conclusion: A process of *local optimization* drove the information seeking process: physicians utilized information that maximized their information gain even though it required significantly more cognitive effort. Implications for the design of health information technology solutions that seamlessly integrate information seeking activities within the workflow, such as enriching the clinical information space and supporting efficient clinical reasoning and decision-making, are discussed.

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1. Introduction

Human are often characterized as *informavores* [1]. We actively seek, gather, consume and share information for satisfying diverse needs [2]. The purpose of information seeking depends on, among other things, specific user needs and tasks at hand. In complex organizational contexts, the ability of humans to access and utilize the necessary task-related information leads to better productivity and performance. But, the unaided mind, no matter how competent, simply cannot focus on all available information for making optimal decisions. Cognitive barriers such as memory capacity limitations, lack of knowledge, information overload affect the optimality of decision-making strategies.

Critical care environments represent a prototypical information-intensive, distributed and collaborative setting [3,4], where significant information is generated by health care professionals (physicians, residents, nurses, and other support staff), and from patient care related events (e.g., bed-side monitors laboratory tests, medication orders). Most often, this information is redundantly distributed across multiple sources, such as paper and electronic records, and physicians face the onerous task of finding, retrieving, and filtering the necessary information for decision-making tasks. The distributed nature of information organization in critical care settings poses significant challenges for physicians in their information seeking activities including: (a) increased patient care time resulting from longer time for finding, filtering and organizing information due to the redundancy in

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available information and (b) increased possibility of missing information due to the distributed nature of information. All of these significantly affect the quality of care, increase the possibility of adverse events and can potentially impact patient safety. With the increasing role of health IT and digital repositories in clinical settings, it is relevant to evaluate the role of technology in supporting (or impeding) clinical reasoning and decision-making [5].

We utilize a cognitively driven approach to characterize the efficacy of physicians' information seeking process, and the structure and nature of clinical information that is retrieved and used for decision-making tasks. While the importance of cognitive science research on understanding the nuances of reasoning and decision-making has been well established, primarily through laboratory evaluations (e.g., [6–8]), we investigate information seeking and decision-making "in the wild," [9] by preserving the constraints of information sources and their availability that physicians encounter in their regular clinical practice.

Insights on the information seeking behavior of physicians can help in identifying the inefficiencies (e.g., process loses) in the physician information seeking process, for developing cognitive models of physicians' information choice behavior and for designing and developing integrated intelligent health IT solutions that can assist in clinical decision making. Additionally, understanding the structure and nature of information used by clinicians during this process can trigger the development of clinical systems that streamline information retrieval and visualization mechanisms.

2. Background and significance

The complexity of patient care is exacerbated in distributed, information-rich critical care environments where physicians have to find the "right information at the right time" for making timely decisions. There is significant empirical evidence that a large percentage of physicians' information needs during the patient care process is often unmet. In a highly cited study, Covell et al. [10] found that only about 30% of a physician's information needs during patient encounters were met. Gorman and Helfand [11] and Codgill et al. [12] report on similar findings based on their empirical studies. Over 70% of physicians' information needs are related to diagnosis, treatment/therapy or drug-related information [13], and time constraints [14] result in significant amount (up to 40%) of the information needs being unmet [12].

Prior research on information seeking draws on the primary assumption that a significant amount of a physician's information needs are unmet. These studies can primarily be classified into two categories: studies that describe the nature of information needs in clinical environments and those that report on the sources of clinical information. Examples of prior work for each of these categories are described below. Currie et al. [15] describe an observational study on the information needs of clinicians while using a clinical information system. They found frequent unmet clinician information needs that were either domain-specific or patient-related. In a related study, Allen et al. [16] investigated the information needs of clinicians as they were using an information system. Based on the analysis, clinician information needs were grouped into seven categories including navigational issues, cross-referencing with other objects, laboratory results, pharmacy-related questions, differential diagnosis (or alternative diagnoses), definitions of terms and miscellaneous information needs.

In the second category, a significant amount of prior research focuses on the various sources of information that were used by clinicians to cater to their information needs. These sources range from paper and electronic records, databases, research literature, professional colleagues, or text books [13]. D'Alessandro

et al. [17] categorized the information seeking behaviors of general pediatricians into time spent on using computers, digital libraries and other information sources. They found that physicians usually depend on more than one source during their information seeking process. They argued that computer resources were the most "effective and time-efficient" mechanism for information seeking. Other researchers found that clinicians relied on their peers, external text-based resources or Internet resources [18,19] for their information needs [20]. While there were differences in the nature of information needs between physicians and other clinicians (e.g., [21]), most clinicians expressed significant difficulty in obtaining "patient, domain and institution-specific information in a timely manner," due to the difficulty in finding the right sources of information [22,23]. Prior research has also described the challenges of finding clinical information in a timely manner, especially in dynamic critical care settings. For example, Ely et al. [24] found that physicians spent on average less than 2 min pursuing clinically relevant information. In a related study, Sackett and Strauss [25] found that information resources had to be accessible within 25.4 s for bedside consultations.

While all of these studies highlight the significant challenges of information seeking in clinical environments as potential reasons for high percentage of unmet information needs, they did not investigate their causal determinants or efficiency of processes involved in clinical information seeking. One notable exception is the study by Patel et al. [5] who found differences in the nature of use of computerized and paper based records during diagnosis tasks. In a study comparing the nature of information in paper and computerized records, they found that computerized records impacted the data collection, knowledge organization and the reasoning process of the physician. Their focus was on elucidating the differences in reasoning process caused by paper and electronic records.

In summary, most prior work on information seeking investigated clinical information needs during the information seeking process and the sources of information used during this process. Our focus is on extending prior work for evaluating the process of clinical information seeking, the structure and content of information that is sought and retrieved, and the utility of the retrieved information for diagnosis and clinical decision-making tasks.

Using an empirical study of real-world information seeking tasks, we develop an information-theoretic perspective on the process of information seeking. We utilize a rational analysis approach [26] that is predicated on understanding the problem being solved, behavioral strategies that are being used to solve the problem and the most importantly, the cognitive mechanism that drives the choice and use of such strategies [26–29]. Other researchers [30,31] have utilized similar approaches utilizing the information foraging theory to evaluate the resource utilization and sharing practices of healthcare teams.

In this paper, we specifically focus on the following: (a) develop an overall perspective on the nature of information seeking in critical care contexts, (b) time utilization across various resources during the information seeking process, (c) the relative usefulness (or utility) of the information gathered from various sources during clinical decision-making, and (d) nature and structure of medical knowledge that is gleaned from the various sources.

3. Method

3.1. Setting

The study was conducted at a large academic hospital in the Gulf Coast area that had over 33,000 admissions in 2010. Our study focuses on a 16-bed "closed" [32] MICU (medical intensive care unit) managed by intensivists. In the unit, both paper and