METHODOLOGICAL REVIEW

Analysis of Complex Decision-Making Processes in Health Care: Cognitive Approaches to Health Informatics

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Decision making by health care professionals is often complicated by the need to integrate ill-structured, uncertain, and potentially conflicting information from various sources. In this paper cognitive approaches to the study of decision making are presented within the context of a variety of complex health care applications. In recent years it has become increasingly accepted that in order to build information systems that can support complex decision making it will be necessary to more fully understand human decision-making processes. Methodological approaches are described that aim to explicate the decision making and reasoning skills of subjects as they perform activities involving the processing of complex information. The paper begins by presenting the theoretical foundations for cognitive analyses of decision making, including discussion of major approaches to the study of decision making in a range of real-world domains, including medicine. Applications of cognitive approaches are then illustrated, including a description of a study in which subjects were asked to “think aloud” in providing treatment decisions for complex medical cases. The resulting protocols were then analyzed for subjects’ use of decision strategies and problems in reasoning. Extension of cognitive approaches to the study of group decision-making processes is also described. Recent approaches are discussed which borrow from advances in the study of human–computer interaction and which utilize video analysis of decision-making activities involving information technologies. Using these approaches it has been found that health care information systems, such as computerized patient record systems, may have inadvertent effects on human decision making. Implications of a cognitive approach to improving our understanding of complex decision making are discussed in the context of developing appropriate computer-based decision support for both individuals and groups.

Key Words: decision making; problem solving; medical cognition; health informatics; cognitive science; cognitive task analysis; technology evaluation; usability engineering; decision support systems; health information systems.

1. INTRODUCTION

It has become increasingly accepted that emphasis needs to be placed in health informatics on understanding the cognitive processes involved in complex health care. A variety...
of approaches to characterizing complex health care decision making have been applied in the design and evaluation of health care information systems, ranging from decision support systems to computerized patient record systems [1]. An improved understanding of cognition will be essential both for evaluating the effects of such systems and for providing input into their iterative development. It has also been argued that an inherent mismatch between the way humans and computers process information may have potentially detrimental effects upon decision making among health care professionals, necessitating improved understanding of complex decision making [2]. Such understanding may be essential for designing computer systems that are capable of effectively supporting human decision processes. This paper examines a number of cognitive frameworks as well as specific methodologies used in understanding complex health care decision making.

Decision making in complex domains can be considered to be a function of the decision task and the expertise of the decision maker. In general, under conditions of high task complexity, heuristic strategies are likely to be applied by decision makers to simplify the decision problem [3, 4]. As decisions become more complex and the available information leads to potentially ambiguous and contradictory interpretations, simplifying strategies may be required to allow the decision maker to act with confidence. For example, high-performance decision making in situations such as fire fighting and telephone triage has been found to be closely related to overall strategies used for interpreting the state of the emergency [5, 6]. In situations typical of emergency and intensive care medicine, there may be a large number of possible interpretations of patient problems, coupled with a lack of clearly defined “gold standards” for choice of action [7]. Constraining decision problems under such circumstances may be extremely difficult and specific strategies selected would be expected to vary according to the expertise of the decision maker.

Making decisions in health care is often complicated by factors such as ambiguity of information, varying interpretations of evidence, and the multiple perspectives and backgrounds of decision makers. These conditions are characteristic of decision making occurring daily in the health care setting. This paper will focus on the approaches and strategies used by subjects of varying levels of expertise in coping with such situations. Decision making becomes complex in the presence of discrepancies or anomalous data that appear to contradict the overall patient presentation or the presumed diagnostic hypothesis [8]. This leads to possibly divergent interpretations of the patient’s state. An understanding of the conditions under which different types of strategies are employed by decision makers to cope with such complex problems is essential to provide a strong foundation for building computer systems to support the decision making of novice through to expert health care workers.

In medicine, the processing of complex data is at the heart of decision making. Strategies for dealing with decision complexity have been found to distinguish experts from nonexperts [9]. Research in the study of medical cognition, as well as in other domains, has indicated that: (a) experts have highly organized knowledge structures, (b) they do not process irrelevant information, and (c) they apply specific knowledge-based problem-solving strategies in dealing with routine cases [10]. Previous work in medicine has shown that the structure of the decision task, including the presence of noncritical cues, affects reasoning patterns of expert decision makers [11]. It has also been found that medical students of differing levels of experience apply different strategies for dealing with contradictory evidence. For example, Arocha et al. [12] found that beginning students may ignore or reinter- pret anomalous evidence, while more experienced students consider concurrent hypotheses to account for contradictory evidence. However, the extent to which such differences apply across broad levels of expertise has remained to be more fully examined and has implications for development of computer-based information systems which will provide context-sensitive support and training, customized to the level of the end user and sensitive to the type of problems encountered in complex decision situations.

2. COGNITIVE APPROACHES TO STUDYING COMPLEX DECISION MAKING

In this section of the paper a number of methodological and theoretical issues in the study of complex decision making are discussed. The concept of a cognitive continuum is introduced for characterizing decision making and the role of expertise is explored, as well as a number of current issues in the cognitive study of complex decision making.

Methodological Issues

Although conceptually similar, medical problem solving and decision making have traditionally been studied using different research approaches. Psychological research in decision making has often focused on the “decision event,” a hypothesized point in time when a decision maker weighs alternatives and chooses a course of action [13]. Although
closely related, as will be described in the next section, the study of medical problem solving has focused on processes that often precede the decision event, e.g., generation of diagnostic hypotheses and overall situational assessment. Over the past several decades, a considerable body of research findings has accumulated in the cognitive study of medical problem solving [9]. Studies have indicated that physicians use a variety of strategies in dealing with uncertain and ill-structured medical problems [14, 15]. For example, in solving diagnostic problems, expert physicians have been shown to be capable of focusing on small sets of related hypotheses and are able to use efficient discrimination strategies for rapidly distinguishing relevant from irrelevant information in diagnostic reasoning [16–18]. Furthermore, the differences between expert processing may depend on the nature of the task being performed, with highly visual areas of expertise involving pattern perception, while other problem-solving domains may require more effortful analysis, even by experts [19]. In the study of medical decision making, greater focus has typically been placed on the analysis of decision outcomes, using application of theoretical perspectives which have emerged from decision theory [20].

The extent to which theoretical frameworks emerging from the study of medical problem solving and reasoning can be extended to therapeutic decision making remains to be clarified and provides motivation for recent work in cognitive research in health care decision making. Exploring the relation between areas which have traditionally been considered the study of problem solving and the study of decision making has remained a challenge. Problem-solving research has often focused on the processes by which solutions are reached and how knowledge is used. In contrast, much of the large literature on decision making has focused on the outcome of the “decision event,” described above. However, a number of researchers have begun to explore the relation between these literatures [21]. Along these lines, it has been argued that methods applied in the study of medical problem solving and reasoning can be usefully applied to the study of therapeutic decision making, thereby extending traditional analyses focusing on decision outcomes to include greater consideration of cognitive processes underlying choice [22]. In the studies reported in this paper, processes considered to be within the realm of diagnostic reasoning and therapeutic decision making are considered.

Research has also been conducted in the naturalistic study of decision making in areas ranging from fire fighting to intensive care medicine. Much of this work has employed nonobtrusive observational study [6], or use of retrospective reports in the analysis of decision making during critical incidents [13]. Some of the results of such study have challenged findings and conclusions drawn from the larger body of traditional, laboratory-based research in decision making which has grown out of a decision-theoretic perspective [23]. For example, it has been argued that a focus of many laboratory studies of decision making on the “decision event” is not representative of many real-life decision problems which are often ill-structured and may require considerable problem-solving processes as a prelude to the development or consideration of decision alternatives. Other researchers have recently focused on the need to examine the ecological validity of experimental tasks in studies of decision making and problem solving [24].

The Cognitive Continuum in Complex Decision Making

In considering the relationship between decision making and problem solving, decision making can be considered a problem-solving process in which the solution is in the form of a decision, typically leading to an action. Consistent with this perspective, important links have been made between research in decision making and related areas of study, such as the study of complex problem solving. There has also been a growing awareness that decision making and reasoning are highly interrelated, although the literatures in these two areas have been somewhat separate as well. For example, studies of deductive reasoning have examined the process of how humans move from premises to conclusions, where subjects may be given premises of an argument and are then asked if a conclusion follows from those premises. In contrast, a typical task in the decision-making literature focuses on the choices made by subjects between actions, with the choices often presented to subjects. According to Johnson-Laird and Shafir [21], there are a number of reasons for considering the relation between decision making and reasoning. For many purposes it may not be productive to strictly separate the two when considering real-world problems, since in everyday situations reasoning and decision making are often highly interwoven, with decision making involving reasoning (i.e., the individual will have to reason in order to make decisions) [25]. Along these lines, Cooper and Fox [22] have argued that research in decision making needs to address to a greater degree the role of cognitive factors, including human memory limitations and specific subject strategies. It is further argued that work is needed to bring methods from the general area of cognitive psychology which routinely deal with problem-solving processes and reasoning into the mainstream study of decision making.

In considering complex decision making, Hammond [26]
has argued that cognitive processes in decision making can be located along a cognitive continuum, which ranges between intuition and analysis. Tasks that require the processing of large amounts of information in a very short time period tend to induce intuitive (i.e., less analytical) processing. On the other hand, tasks that involve quantitative information, presented in a sequential fashion may induce more analytical processing. Other factors that affect where a decision may fall on this continuum include the effects of failure (e.g., the decision maker may tend to become more analytical when intuitive judgments fail, or become more intuitive when careful analysis fails), task complexity as well as the experience and expertise of the decision maker. For example, under conditions requiring a rapid response, an expert’s decision making may fall more on the side of intuition; i.e., based on prior experience, a decision may be made without extensive conscious deliberation. According to Hammond, it may be possible that cognitive activity in decision making may move along the continuum during complex problem solving, i.e., oscillate between intuition and analysis [27, 28]. The cognitive continuum provides a useful framework for considering a number of cognitive models (described below) ranging from those focusing on recognitional processes to models that emphasize processes involving explanation and reasoning with evidence. It also is consistent with models of skill acquisition, where skill in performing a given task moves through stages of deliberate and mindful practice until it eventually becomes automated [29].

At one end of the cognitive continuum a number of cognitive models have appeared that focus on recognitional aspects of decision making in complex domains. A perspective on decision making based on recognitional processes is consistent with work from the study of expertise in problem solving and reasoning. For example, work by Chase and Simon [30] indicates that expert chess players are adept at quickly recognizing arrangements of chess pieces from previous games. In the area of medical diagnosis, Patel et al. [17] found that expert physicians are adept at quickly filtering out irrelevant information and focusing on relevant cues in doctor–patient interactions. Other related findings have emerged from the study of cognitive processes involved in expert diagnosis involving radiographic images, where experts were found to develop finely tuned mental representations of patient anatomy which drive the physicians’ perception and allow them to rapidly recognize important features in the image [16].

The Recognition-Primed Decision Making (RPD) model [31] is a recent cognitive model which focuses on recognitional processes in describing how critical decisions are made by experienced decision makers. The area of research from which the model was developed was the study of the decision making of highly experienced urban fireground commanders [13]. In considering analysis of retrospective reports Klein and Calderwood found that experienced decision makers do not work out all possible contingencies but rather develop a workable solution to decision problems (consistent with Simon’s [32] conception of bounded rationality): “It was difficult to represent the phenomenological accounts of these decision processes in any meaningful way within the decision tree framework. Indeed, the fireground commanders resisted any attempt to characterize their roles in terms of ‘making choices,’ ‘considering alternatives,’ or ‘assessing probabilities.’” Klein and Calderwood go on to state that the firefighters instead “saw themselves as acting and reacting on the basis of prior experience, planning, monitoring, and modifying plans to meet specific constraints.” As a consequence of findings from such studies, an emphasis has recently emerged on the relation between decision-making processes and aspects of problem solving, in particular the role of problem representation and situation assessment in skilled performance in professional domains, including medicine [33].

Situation assessment refers to the identification and clarification, by the decision maker, of the state of the decision problem [34]. This includes identification of goals, the assessment of how critical the problem is, and comparison of the current state of the world to previous experience. Research from a number of domains [6, 35, 36] has implicated the importance of situation assessment, i.e. “sizing up” a decision problem and understanding a situation in terms of its similarity to previously encountered experiences. Situations that are highly familiar to the decision maker may lead to automatic response. On the other hand, situations that are unfamiliar, or only moderately familiar to the decision maker, may invoke analytical reasoning.

At the analytical end of the cognitive continuum are recent models of decision making emphasizing the role that explanatory processes play in reasoning and decision making [37–39]. From this perspective, reasoning about evidence is viewed as a central process in complex decision making. Using evidence, in conjunction with stored knowledge about similar events, the decision maker attempts to develop a coherent explanation, using schemata to guide construction of a plausible story and to fill in missing information. According to explanation-based models, decision makers construct summary representations of evidence, which are used
as a basis for making decisions. These representations are important in facilitating the active process of evidence comprehension, directing inferencing and ultimately reaching a final decision. Pennington and Hastie [37] argue that differences in decision making by individuals of different levels of experience lie largely in the evidence evaluation stage of the decision process. These differences are reflected in the structure of the explanations that they generate. Furthermore, the structure of the causal model that is constructed to explain evidence will be specific to the decision domain. For example, according to Pennington and Hastie [37], physicians construct an explanation of findings in terms of one or more disease categories. In related work, Patel and Groen [9] have found essential differences in the structure of pathophysiological explanations of clinical cases given by subjects of varying levels of medical expertise, with experts producing explanations that are more coherent and that contain less extraneous detail than explanations by nonexperts.

The Role of Expertise in Medical Reasoning and Decision Making

In medicine, expertise can be considered to exist along a continuum, ranging from novices (i.e., medical students), to experts possessing highly specialized medical knowledge [15]. Development of medical expertise appears to be marked by transitions which reflect underlying reorganizations of knowledge and increases in mastery of domain tasks [9]. Although the focus of much research is on the “expert,” with novice performance being used for comparison, a broader perspective encompasses an understanding of the progression from novice to expert. Research in medical cognition has provided support for findings of essential differences in the reasoning strategies and knowledge organization of physicians of varying levels of expertise. For example, Feltovich et al. [40] found that expert physicians possess elaborate and highly structured knowledge bases capable of supporting efficient reasoning. In a series of studies conducted by Patel and colleagues, subjects of differing levels of expertise were presented with short descriptions of medical cases and were asked to provide explanations of the underlying pathophysiology. Applying methods of propositional analysis, Patel and Groen have characterized the reasoning processes and strategies of novices and experts [9]. From these studies [9, 41] it has been found that directionality of reasoning is predictive of diagnostic accuracy, with experts producing correct diagnoses typically using a forward reasoning strategy (i.e., from data to hypotheses). In contrast, nonexperts and experts outside of their domain who produce incorrect diagnoses were found to use predominantly backward reasoning (i.e., from hypotheses back to data); however, the two types of reasoning may become more mixed as problem-solving tasks become more complex.

Although a large body of results has accumulated in the study of medical cognition, the emphasis of the majority of studies has been on diagnostic reasoning and problem solving (i.e., analyses of cognitive processes occurring prior to treatment choice). Research examining treatment choices and decision making regarding patient management has more typically employed approaches which have emerged from the traditional judgment and decision literature, with a focus on subjective expected utilities and decision outcomes. However, cognitive studies of therapeutic decision making [20] indicate that a process-centered approach to the study of decision making can also provide considerable insight into understanding physicians’ decision-making strategies. In one cognitive study of therapeutic decision making, Kuipers et al. [42] presented three pulmonary physicians with a case description involving a patient with a pulmonary condition. Verbal protocols were collected of the physicians’ responses to the cases as they provided treatment decisions. Kuipers and colleagues [42] found that the process of physician decision making “resembled an incremental, sequential-refinement planning algorithm, where a complex decision is broken into a sequence of choices to be made with a simplified description of the alternatives.” Based on protocol analysis, Kuipers and colleagues argue that medical decisions are not made after gathering all the facts, but are instead constructed (through an incremental planning process, allowing complex medical problems to be solved with limited processing resources).

In line with a trend toward studying reasoning, problem solving, and decision making in realistic tasks and real-world contexts [31], research has been conducted involving analysis of decision making by teams of physicians and nurses in critical health care settings, such as the intensive care unit [43] and the operating room [33]. In other naturalistic studies, decision-making strategies in emergency telephone triage situations have been examined, focusing on assessing the relationship between decision-making strategies and the underlying knowledge of the decision maker. For example, Leprohon and Patel [6] found that in high-urgency situations, nurses use simple rules that often lead to accurate decisions (which however often do not correspond to their retrospective explanations of their actions). In moderate- to low-urgency conditions, accuracy in the
development of plans of action is related to the nurses’ ability to assess the overall state of the emergency situation.

Issues in the Cognitive Study of Complex Medical Decision Making

A number of issues remain as challenges to research in medical decision making. In particular, work is needed in understanding the relationship between results and empirical findings from the study of medical problem solving with those from research in therapeutic decision making. The question remains as to what extent findings from the study of problem solving and reasoning apply or are different from those that relate to therapeutic decision making. Another area that warrants investigation is that of the relation of findings emerging from recent study of decision making in naturalistic settings, typically involving observational methods or retrospective reports (e.g., the work of Klein [31] and Patel et al. [43]) with results obtained from experimental laboratory-based studies. Some researchers have considered the naturalistic approach to represent a new paradigm in the study of decision making (e.g., Orasanu and Connolly [44], and Cannon-Bowers et al. [45]) that strongly challenges the results from more traditional psychological and cognitive studies [13]. However, as indicated in this Review, there may be a number of parallels and consistencies among findings from both naturalistic and experimental studies. The extent to which such parallels hold is an area that requires further study and which has considerable implications for future directions in the study of decision making and problem solving in general.

Decision making in medicine typically requires the integration of complex evidence from a variety of sources. This evidence may be conflicting or lead to ambiguous interpretation of a patient’s state. Differences in approaches to dealing with conflicting and anomalous data have been found in a number of domains, ranging from education and theory formulation in science [46, 47] to medical diagnosis [15]. Understanding how experts as well as nonexperts deal with medical cases that contain anomalous evidence is of great importance in characterizing the role of expertise in medical decision making. For example, studies have shown that experts may switch from forward-reasoning to backward-reasoning strategies depending on the complexity of the decision task. It has been found that when “loose ends,” i.e., anomalous data not directly related to the main diagnosis, are included in a case, the expert’s pattern of forward reasoning may be disrupted [11]. The nature of the decision task, including its difficulty, the extent to which the task is nonroutine, and the level of ambiguity of evidence, are all factors which have remained to be more fully explored when considering differences in expert and novice decision strategies. Although findings have emerged indicating essential differences in the reasoning and decision-making processes of experts and nonexperts, work is needed in elucidating the conditions under which such differences appear, particularly the effect of complexity of evidence on decision strategies.

Finally, the relation of research investigating processes involved in complex decision making to the development of improved decision support systems needs to more fully explored. It has been argued [1] that in order to provide decision support to health care workers that is both sensitive to the type of problems that occur in real situations and also sensitive to their background and expertise, cognitive studies of decision making will be essential.

3. APPLICATION OF COGNITIVE METHODS TO THE ANALYSIS OF DECISION MAKING: IMPLICATIONS FOR HEALTH INFORMATICS

Despite the considerable amount of effort and research that has gone into the development of high-level decision support systems for use in health care, these systems have yet to penetrate deeply into practical day-to-day medical use [48]. Some researchers have argued for more extensive clinical evaluations of existing systems [49], while others have argued that the process of decision support development itself needs to be critically reexamined [50]. It has recently been argued that more work is needed in developing and refining appropriate methods for analyzing complex clinical problems and situations and determining how physicians cope when faced with difficult medical cases [1]. In the remainder of this paper we discuss a number of methodological approaches to the study of such complex health care decision making which have grown out of the theoretical frameworks discussed in the first part of the paper.

Cognitive Task Analysis

An important approach which has emerged over the past two decades and which has led to a number of powerful methods for assessing processes involved in complex decision making (along the entire cognitive continuum described in the previous section) is known as cognitive task analysis. In contrast to traditional approaches to the study of decision making which focus on the “decision event” (a hypothesized point in time when the decision maker is supposed to weigh
Alternatives and arrive at a decision), cognitive task analysis aims to explicate the cognitive processes that occur both prior to and during complex decision making. In addition, cognitive task analysis aims to take into account the complex situational factors that affect decision making as well as the effects of prior knowledge and expertise brought to bear on decision making by the decision maker [51].

The term “cognitive task analysis” first appeared around 1980 and has drawn on a number of research streams [51] including the following:

1. The study of expertise in the study of problem solving as a basis for development of computer-based intelligent tutoring systems [52].
2. Extension of usability engineering to study of complex real-world problem solving as basis for “cognitive” system engineering [53].
3. Study of human–computer interaction focusing on analysis of the process of computer use [54].
4. Ethnographic study of workplaces as “cultures” and the effects of introduction of technology [55].
5. Naturalistic research involving observational study and use of retrospective reports by decision makers in real-world areas such as fire fighting and medicine [13].

Although the methods applied in cognitive task analysis vary, as the list of research streams given above might imply, there are a number of common threads to such approaches [56]. These include an emphasis on understanding the processes involved in complex decision making and reasoning, which is in contrast to much of the traditional work in decision making and medical informatics, where the focus has been less on understanding complex cognitive processes and more on assessment of decision outcomes. Second, the approaches attempt to take into account and characterize the effects of experience and prior knowledge on decision processes, which also contrasts to much of the traditional normative research in areas including the psychological study of decision making. Finally, the approaches typically identify problems that occur in decision making and reasoning (with or without using technology) by subjects of varying levels of expertise. A number of these methods provide a framework for studying complex health care decision making and for providing practical input into the selection and design of health care decision support systems. Several examples of particular application of such methods will be described in the remainder of this paper.

**Cognitive Task Analysis of Complex Decision Making in Intensive Care**

In this section, we provide an example of application of cognitive task analysis to studying the processes involved in complex decision making in intensive care medicine [1]. The study we will use to illustrate the overall approach involved the examination of decision making by medical students and physicians in dealing with pulmonary embolism (PE), a condition frequently encountered in intensive care medicine. PE is a respiratory complication typically arising from blood clots originating in the deep veins of the legs and eventually leading to the obstruction of the pulmonary arteries, respiratory compromise, and potentially death. Both the diagnosis and treatment of PE may be extremely complex from a cognitive point of view, requiring the weighing of evidence from the patients’ overall clinical presentation as well as evidence from specific tests and scans. In conducting this study it was believed that these types of conditions which complicate decision making are typical of many decision situations in health care. PE is commonly encountered, and yet the symptom presentation is complex and there are many nuances to its diagnosis and treatment.

In conducting the study, task materials were developed (with the aid of an expert physician) that provided descriptions of patients with varying degrees of evidence for pulmonary embolism. Based on an initial investigation of physicians’ diagnosis of this condition it was found that clinical evidence for PE is typically weighed in conjunction with results of a lung scan. Twelve written cases were designed which varied in terms of clinical and lung scan evidence for the condition—i.e., two cases were developed for each of six types of cases representing combinations of three levels of PE probability based on lung scan results (low, intermediate and high probability of PE) with two combinations of clinical evidence (low and high probability of PE)—see Table 1. Some of the cases represented consistent evidence

<table>
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<th>Case type</th>
<th>Probability lung scan for pulmonary embolism</th>
<th>Clinical evidence for pulmonary embolism</th>
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<tr>
<td>1</td>
<td>Low</td>
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Subjects who participated in the study included eight medical students (novice subjects), eight residents (intermediate level subjects), and eight intensive care specialists (expert subjects). During the data collection, each subject was presented with the 12 cases one at a time and was asked to read the case and “think aloud” in deciding on a course of action for each patient case. The resulting think-aloud protocols were audiotaped and transcribed verbatim for analysis of decision strategies and problems in decision making. In order to analyze the transcribed protocols a coding scheme was developed to identify decision processes and reasoning strategies used. This included identification of choice of treatments, generation of diagnostic hypotheses as well as requests for information and processes involved in arriving at a situation assessment (see [36] for details).

In summary, the findings indicated general differences in strategies for dealing with ambiguity of evidence across subjects of differing levels of expertise. In particular, when faced with a clinical picture which was in contrast to lung scan results (e.g., high clinical evidence for PE in conjunction with a lung scan indicating a low probability of PE), the medical students tended to base their decisions on the results of the scan results. In contrast, the expert physicians were much more likely to reject an anomalous piece of evidence (e.g., a low probability lung scan) in favor of the overall clinical pictures. Intermediate-level subjects (residents) dealt with such conflicting evidence by attempting to defer the decision if possible. A second finding which emerged from the analysis of the think-aloud protocols was that expert physicians focused on developing a strong situation assessment for each case, from which they were then able to interpret individual pieces of data. In general expert subjects stated they would require further detailed situational information and generated significantly fewer diagnostic hypotheses, investigations, and treatments than intermediate (resident) subjects.

This type of research has a number of implications for the design of computer-based information systems to support human cognitive processing and information needs [1, 36]. Along related lines, it has been argued that a closer relationship should be developed between design of such systems and cognitive research in medical reasoning and decision making. Although improved computer-based support of complex decision making will require a greater understanding of the cognitive processes of potential users of such systems, the identification and extraction of knowledge needed for developing decision support that adequately meets the cognitive needs of users has proven to be a formidable challenge. In this paper, it is argued that in-depth cognitive analysis of medical decision making in domains targeted for decision support may be necessary where problem complexity makes conventional systems analysis and knowledge acquisition techniques inadequate. For example, in many complex medical domains (including much of intensive care and emergency medicine) physicians are often not consciously aware of how they cope with decision complexity, their strategies for dealing with uncertain and ill-defined problems, and how factors such as experience and expertise affect their decision making and those of their co-workers. In such contexts, scientific approaches to analyzing decision strategies and identifying heuristics, using methodological approaches such as cognitive task analysis, can be used to assess how complex decisions are handled and how knowledge-based decision support systems can be designed to facilitate and enhance the decision making of users of varying levels of expertise.

The importance of having an improved understanding of cognitive processes in complex domains such as medicine includes development of a sound basis for strategically targeting computer systems to provide assistance with decision-making tasks and processes that humans find difficult or error prone. Furthermore, in order to develop knowledge-based decision support systems that can provide flexible, context-sensitive support for health workers (of varying levels of expertise and training), methodologies for understanding and characterizing differences in reasoning and decision making are needed. Specifically to assist human decision processes, extensions of the cognitive approaches presented in this paper can be applied in characterizing the following attributes of decision making: (a) the skills that decision makers need to bring to bear on the decision-making process, (b) the strategies actually used by subjects of varying levels of expertise in coping with complexity and specific constraints in decision making, and (c) the types of problems encountered by subjects of varying levels of expertise—essential for identifying the problems areas that arise which need to be supported and identifying the nature of effective support for cognitive processing (e.g., including extending the range of strategies the decision maker may be aware of, and providing specific assistance in aspects of decision-making processing, such as situational assessment).
Extension of a Cognitive Task Analysis Approach to Study of Physician–Computer Interactions during Health Care Decision Making

As described above, one approach to the study of complex decision making involves the recording of subjects (i.e., health care workers) as they “think aloud” while making complex decisions. In a series of studies investigating the effects of the use of information technology on health care decision making, a similar approach was extended to include full video recording of physicians interactions with information systems as they (a) thought aloud while using a patient information system in diagnostic reasoning and (b) interviewed patients while at the same time entering information into a patient record system. The techniques for conducting such studies have involved integration of methods from the emerging area of usability engineering [36, 57, 58] to the study of health care decision making mediated by advanced information technologies. The approach to recording the cognitive processes and interactions of physicians with patients in real health care contexts also borrows from cognitive task analysis with its emphasis on recording of processes involved in complex decision-making situations.

In a number of studies applying such hybrid methodologies, we have found that the organization of information as it is presented on the computer screens of systems (e.g., electronic patient records and decision support systems) can greatly influence the physicians’ reasoning processes and patterns. In some cases specific screen arrangements can greatly affect the direction of the physicians’ information gathering when attempting to arrive at a diagnosis or treatment plan—an effect which we have termed “screen-driven” diagnostic behavior [59]. Current work along these lines has included application of cognitive task analysis methods in the distance evaluation of use of information systems over the World Wide Web [60].

From Individual to Group Decision Making: Application of Cognitive Task Analysis in the Study of Collaborative Decision Making

In another line of research, theoretical frameworks and methods emerging from the study of individual decision makers in health care are being extended to studies involving group and team decision making. For example, we have recently conducted studies of the communication among nurses and physicians in an intensive care unit [61]. Two groups of subjects, consisting of nurses in an intensive care unit, and a second group consisting of physicians in that unit, met in a series of meetings to discuss problems occurring in an ICU (too many blood gas analyses). The sessions were conducted as problem-solving sessions with the discussion being audio and video recorded as the groups identified problems and suggested solutions to those problems in the unit. Extending the approach to coding and analysis of individual decision strategies, described above in relation to the study of intensive care decision making, the group meetings were coded and analyzed to identify hypotheses proposed (as to organizational problems), evidence provided in support of arguments, and proposed solutions. The results indicated a convergence of identified problems and solutions and has since been used to feedback into the optimization of the ICU under study.

An area of research of considerable relevance to health care is emerging from the study of human–computer interaction and team decision making [62, 63]. Much of this work has suggested that there may be important parallels between theoretical frameworks and potentially among methodologies used for study of individual decision making and that of groups. Indeed, specific aspects of team decision making, including the group’s use of simplifying strategies in dealing with complex cases, can be considered in the context of theoretical frameworks which have emerged in the study of individual decision making. We are currently undertaking research studying group decision making in medical education involving the video recording of small group teaching sessions. This research aims to determine the extent to which theoretical and methodological frameworks from the study of individual decision making (as in the study of decision making involving pulmonary embolism described above) apply to the study of group decision making and the extent to which an understanding of group decision making can form the basis for selection and design of group decision support systems.

4. CONCLUSIONS

In recent years it has become apparent that the design of computer systems in medicine needs to take understanding of how physicians of varying levels of experience process medical information and make difficult decisions into greater consideration. This is especially relevant in the area of designing decision support systems to facilitate and support the higher level decision making processes of users ranging from novices to intermediates to experts. Despite the considerable amount of effort and research that has previously
gone into the development of computerized expert systems and knowledge-based medical decision support systems, these systems have not penetrated deeply into practical day-to-day medical use [48]. It has been argued that research in decision support in general has focused on incorporating the latest of information technology while paying far less attention to whether these new support systems are compatible with the psychology and needs of decision makers in their day-to-day practice [64]. Along these lines, it has also been argued that there is often a fundamental mismatch between the way humans process information during decision making and the way it is processed by computers.

Knowledge of how information is processed by decision makers of varying levels of expertise may be critical in the development of effective decision support tools in providing relevant and up-to-date support for actual application in daily situations. An improved understanding of the cognitive processes of health care workers will be critical to the success of such technology in actually changing and improving practice. Along these lines, a distinction can be made between merely automating a process and changing a process in a way that is useful. If a change is perceived by health care workers as being useful, it will more likely be accepted and lead to improved practice. Such work will be needed to form the basis for the development of information retrieval systems designed to provide users with context-sensitive help and automated retrieval of information resources relevant to the needs of health care workers. In addition, research into assessing the effects of health care information systems on reasoning and decision making will be essential, particularly as it has been shown that small changes in the design of the user interfaces of such systems can potentially have dramatic impact on physician decision making processes [59].

From the review of literature presented in this paper it is clear that there are a growing number of trends and developments in the study of complex decision making that have considerable significance for understanding health care decision making as well as for potentially improving it. In conclusion, cognitive approaches to the study of decision making may provide a sound basis for understanding the strategies and problems encountered by decision makers.

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REFERENCES

ANALYSIS OF COMPLEX DECISION MAKING PROCESSES


