Analysis of Medical Decision Making: A Cognitive Perspective on Medical Informatics

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ABSTRACT

The improved support of complex medical decision making will require a greater understanding of the cognitive processes of physicians. Decision making in medicine often involves the careful weighing of uncertain and ill-structured information from various sources. In this paper a cognitive approach to analyzing complex intensive care decision making is outlined. The study described involved the presentation of case descriptions of systematically varied complexity, to two levels of physicians: intensive care residents (intermediates) and intensive care specialists (experts). Subjects were asked to "think aloud" in providing treatment and management decisions for the cases. The audiotaped protocols were then analyzed for the use of decision strategies and for key aspects of decision making. It was found that expert subjects tended to focus on developing a more refined situational analysis of the decision problem. The study results are being used in the design of a system for aiding physicians in making complex decisions in intensive care medicine.

INTRODUCTION

It has recently been argued that a closer relationship should be developed between medical informatics and cognitive research in medical reasoning and decision making [1]. According to Blois and Shortliffe [2] "To develop computer-based tools to assist with decisions, we must understand more clearly such human processes as diagnosis, therapy, planning, decision making, and problem solving". Along these lines, it is argued that the development of computer systems in medicine needs to take into account how physicians of varied levels of experience process medical information and make difficult decisions. This is especially relevant in the area of development of medical decision support aimed at facilitating and supporting the higher level decision making processes of physicians. In this paper some recent research in the area of understanding how physicians make complex decisions will be described, along with the relevance of this work for the development of training and computer-based decision support.

Background

Recent research in the area of medical decision making has revealed the use of varied strategies by subjects in coping with complexity of medical situations. From a theoretical perspective, strategies can be considered as being methods for simplifying decision making, either by limiting the amount of information processed or by making processing of that information easier. When faced with conditions of high task complexity or time pressure, particular "simplifying" strategies are likely to be adopted. It is hypothesized that the strategies used by physicians in coping with decision complexity will vary considerably with differing levels of expertise. Related work by Leprohon and Patel [3], involving the analysis of emergency decision making of nurses responding to 9-1-1 emergency calls, has indicated that high performance decision making is related to the decision maker's approach to the evaluation of the whole emergency situation. This is consistent with research from field studies of decision making in a number of naturalistic settings, indicating the importance of situation assessment in expert decision making [4, 5].

Over the past several decades, a considerable amount of research has accumulated in the cognitive study of medical diagnostic reasoning and problem solving [6]. Studies have indicated that physicians use a variety of strategies in dealing with uncertain and ill-structured medical problems. For example, in solving diagnostic problems, expert physicians are capable of focusing on small sets of related hypotheses and are able to use efficient discrimination strategies for distinguishing relevant from irrelevant information in diagnostic reasoning [7]. However, the extent to which such research findings, emerging from the study of medical diagnostic reasoning, can be extended to medical decision making (in treatment and management) remains to be explored. Such research would have important implications for the development of computer systems for supporting complex decision making.

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The work described in this paper examines how physicians of differing levels of expertise deal with complexity in decision making in the treatment and management of pulmonary embolism. The management of this condition is typical of other medical situations in that it requires the careful consideration by the decision maker of evidence from a number of sources.

Although a variety of observational field studies have recently appeared in the study of complex decision making [8], there is the need to further develop methodologies and controlled studies that are sensitive to the complexity of medical decision making tasks and that are at the same time experimentally rigorous. Ideally, this work should take into account the level of expertise and knowledge of the decision makers. The approach described in this paper extends the "expertise approach", from the cognitive study of physician problem solving and decision making [9] to the study of complex decision making by physicians. Subjects consist of physicians with varied domain expertise: residents and intensive care specialists. The approach involves the use of a controlled experimental design in conjunction with the novel application of analytic techniques based on cognitive research.

Cognitive Analysis and the Development of Decision Support and Training Systems

Despite the considerable amount of effort and research that has gone into the development of knowledge-based medical decision support systems, these systems have yet to penetrate deeply into practical day-to-day medical use [10]. Some researchers have argued for more extensive clinical evaluations of existing systems [11], while others have argued that the process of decision support development itself needs to be critically re-examined [12]. It has recently been argued that more work is needed in developing and refining appropriate methods for analyzing complex clinical problems and situations [13] and determining how physicians cope when faced with difficult medical cases [14]. In this paper, the methodology employed and the empirical findings resulting from its application will be considered in the context of developing medical decision support and training.

METHODS

Written case descriptions were presented to subjects of two levels of expertise - 5 intensive care residents (intermediates), and 5 full-time intensive care specialists (experts). The case descriptions used in the study were designed to systematically vary the levels of two critical types of evidence: (1) lung scan evidence for the presence of pulmonary embolism (described by three levels: low, intermediate and high probability of pulmonary embolism) and (2) clinical evidence for the presence of pulmonary embolism (two levels: low and high). Thus, there were six types of cases, one for each combination of the three commonly encountered levels of lung scan evidence and two clinical evidence levels. Two case descriptions were designed for each of the 6 case types and therefore 12 cases in total were designed. The following is an example of one of the cases (representing high clinical evidence in conjunction with high lung scan evidence for pulmonary embolism):

> A 65 year old man developed severe pneumonia of unknown etiology. He required ventilatory support and was paralyzed for four days. He gradually improved when 10 days later he developed severe pain in the left popliteal fossa and marked swelling of his calf. Three days later he suddenly became short of breath and developed a cough productive of small amounts of blood-flecked sputum. On examination he was agitated and cyanotic. Pulse 130 regular; BP 90/70; Respiration 31 (labored and using accessory muscles); Temperature 38.2 C. On auscultation rales were heard on the right, along with a pleural friction rub. The posterior aspect of his thigh and calf were acutely tender and there was moderate pitting oedema around the ankle. Homan's sign was positive. HB 13; WBC 20,000; PO2 63; PCO2 28; PH 7.48. Chest X-ray shows multiple infiltrates on the right with a small right pleural effusion. EKG shows a right axis deviation with occasional VPC's. V/Q scan showed a marked mismatch highly suggestive of embolus.

During the experimental sessions, each subject was presented with the cases, one after the other. The cases were initially ordered randomly. Each subject was asked to: (1) read the case and think aloud as they decided on a course of action to be taken in dealing with that case (i.e. provide the therapeutic and management plan), (2) indicate whether they would treat with the information given (and if not, what information would be needed), and (3) suggest a differential diagnosis for the case.

The verbal protocols of the subjects were transcribed and coded for key aspects of clinical decision making. A scheme for coding the subjects' protocols was devised, based on methodological and theoretical considerations in the analysis of protocol data from a related number of areas in cognitive research. Based on work by Patel et al [6], the scheme includes categories for coding problem solving and reasoning strategies used, including generation and testing of diagnostic hypotheses. In addition, the analysis included coding for critical aspects of decision making, including the choice of actions, investigations etc. Based on the results of recent empirical work, indicating the importance of situation assessment in real-world decision making [8], an additional aspect of the coding scheme was the inclusion of categories for coding the framing of the decision making problem.

Categories related to decision making were modified from those used by Kuipers, Moskowitz and Kassirer [15]. The main categories included in the coding scheme applied are the following: *assess situation, compare alternatives (concurrently), choose investigation, choose treatment, choose other action, review data, consider hypothesis, increase support for hypothesis,* and *decrease support for hypothesis.*

The procedure for coding involved segmenting the transcripts of the subjects' think aloud protocols, and then coding groups of segments, according to the scheme given above. In addition to coding each protocol for aspects of decision making and problem solving, each protocol was characterized by the experimenters according to the specific and higher-order strategies used by the subject in dealing with each case, using an approach modified from Elstein, Holzman, Belzer and Ellis [16].

RESULTS

The decision rules used by physicians for the experimental conditions are presented in Table 1. For each of the six types of cases, the table gives the outcomes of the physician's management decisions, as well as the percent of cases (for each case type) where a particular treatment plan was recommended. As can be seen, for cases representing low probability lung scan in conjunction with low clinical evidence, and for cases consisting of high probability lung scan in conjunction with high clinical evidence, decision making was consistent across all physicians. In contrast, for cases involving the other combinations of clinical and lung scan evidence, the decisions varied considerably, as can be seen from Table 1.

Table 1. Number and Percent of Subject-Generated Protocols Described by Decision Rules (Grouped by Case Type 1-6)

	Number	Percent
1. If low probability lung scan + low clinical evidence		
a. Do not treat for PE	20	100
2. If low probability lung scan + high clinical evidence		
a. Do not treat for PE (rule out PE)	6	30
b. Treat for PE immediately	7	35
c. If pending investigations are positive then treat for PE	5	25
d. Defer decision - assess further	2	10
3. If intermediate probability lung scan + low clinical evidence		
a. Do not treat for PE (rule out PE)	3	15
b. Treat for PE immediately	6	30
c. If pending investigations are positive then treat for PE	8	40
d. Defer decision - assess further	3	15
4. If intermediate probability lung scan + high clinical evidence		
a. Do not treat for PE (rule out PE)	6	30
b. Treat for PE immediately	11	55
c. If pending investigations are positive then treat for PE	1	5
d. Defer decision - assess further	2	10
5. If high probability lung scan + low clinical evidence		
a. Do not treat for PE (rule out PE)	10	50
b. Treat for PE immediately	4	20
c. If pending investigations are positive then treat for PE	3	15
d. Defer decision - assess further	3	15
6.If high probability lung scan + high clinical evidence		
a. Treat for PE immediately	20	100

PE = pulmonary embolism

Table 2 provides commonly applied higher-order strategies used by subjects in dealing with the complex cases, where the level of lung scan evidence differed from the level of clinical evidence. For each subject, the number of protocols that can characterized by each of four higher order strategies are given in the table. These decision strategies were derived by noting that there were four approaches common to groups of subjects. The majority of the intermediate (residents) physician's decision making could be described by focusing on lung scan evidence, clinical evidence or risk factors. In contrast, a strategy commonly used by expert subjects involved the deferral of an immediate treatment decision, pending the results of a further assessment of the decision situation (i.e. results of tests and investigations).

The results from the analysis of coded protocols are summarized in Table 3, which presents the percentage of total segments coded for each aspect of decision making and reasoning in the coding scheme described above. The percentages are listed for both intermediate (i.e. residents) and expert subjects.

Table 2. Number of Protocols Described by Higher-Order Decision Strategies for Residents (R1-R5) and Experts (E1-E5) in Response to Complex Cases (Case Types 2-5)

Strategy	Subjects									
	Residents					Experts				
	R1	R2	R3	R4	R5	E1	E2	E3	E4	E5
Strategy 1: Focus on scan evidence	1	2	6	3	6	0	1	0	0	1
Strategy 2: Focus on clinical evidence	5	4	2	4	2	5	3	4	5	5
Strategy 3: Focus on risk factors	1	2	0	1	0	0	0	2	1	1
Strategy 4: Stabilize and defer decision (assess further)	1	0	0	0	0	3	3	2	1	1

The most notable difference between experts and intermediates was in the category of situation assessment, with expert protocols containing a much greater percentage of segments dealing with this aspect of decision making and problem solving. Other differences included the tendency for intermediates to choose more investigations and treatments. This is consistent with findings from work by Patel et al [6] that indicates an "intermediate effect", where immediate level subjects (i.e. residents) were found to make many requests for laboratory tests, as well as engaging in extraneous search in problem solving.

As can be seen from Table 3, both group of subjects had a relatively large percentage of segments dealing with the generation and testing of diagnostic hypotheses. Indeed, the analysis indicated that segments dealing with consideration of diagnostic hypotheses (regarding the patient's underlying problem) were highly embedded within segments dealing with decision processes (e.g. regarding choice of treatment).

Table 3. Percentage of Segments of Verbal Protocols (for both Residents and Expert Subjects) Belonging to Each Coding Category

Category	% of Total segments coded Residents	Experts
Assess Situation	21	46
Compare Alternatives	1	1
Choose Investigation	19	7
Choose Treatment	17	6
Choose other action	3	4
Review data	7	7
Consider hypothesis	24	16
Support hypothesis	2	5
Rule out hypothesis	2	3
Provide explanation	3	4

DISCUSSION

In the present study, strikingly different types of strategies were found to be employed by expert and intermediate physicians in situations involving the consideration of complex and sometimes contradictory evidence. Intermediate physicians (residents) were found to make decisions based on selective information (e.g. lung scan results or laboratory results). Expert physicians often deferred decision making, when possible, pending further information. In addition, expert physicians focused on developing a more refined assessment of the situation, as evidenced by the results of the coding of the verbal protocols. In several cases, expert level physicians stated that they would defer decision making pending their own personal examination of the scan or X-ray data. In contrast, none of the intermediates doubted the written summary of the scan data (which is how this information is normally presented to them). Although the experts tended to focus more on aspects of the patient's situation, they also indicated that they would order fewer laboratory tests and investigations than what was indicated by intermediates. The type of information requested by the experts was either of a more perceptual nature (e.g. consideration of the color of the patient's skin) or related to the patient's history and events during hospitalization (e.g. did the patient have problems upon leaving the operating room?).

Implications for Decision Support and Training Systems

The empirical findings from this research have a number of important implications regarding the development of decision support and training systems for complex medical decision making. As described above, the empirical study conducted has characterized key differences between intermediate and expert physicians in terms of their use of decision strategies and more specifically, their situational assessment. This work has implications for the selection of the type of high level decision support that would be useful in this particular domain - e.g. the empirical findings argue for the need for intensive care decision support capable of assisting intermediate level physicians in developing and refining their overall situational assessment ability. It has recently been argued [4], that decision aids specifically designed to support situation assessment should help a less experienced decision maker "to see the problem through the eyes of an expert". However, in this paper it is argued that research is needed in understanding how experts actually deal with decision problems and how their cognitive processes differ from less than expert decision makers (who are to be supported). Towards this goal, empirical work and novel methodologies such as those we have described, can form an important initial step in determining the type of decision support needed and can provide assistance in defining the nature of the support to be developed.

Based on the empirical results, we are currently working on the design of a high level decision support system for assisting physicians with situational assessment in intensive care medicine. The system will consist of a hypermedia reference source with context sensitive decision support. The system is being designed to provide assistance to residents in training in intensive care by providing guidance in deciding when to attend to different sources of information and by making users aware of decision strategies that are not being considered. Ongoing work, based on our empirical findings, also includes the design of training systems for teaching medical students and residents effective approaches to complex intensive care problems, as identified from our empirical research.

The methodology described in this paper can be applied in the analysis of complex decision making in a variety of areas in medicine that require high level decision support. By employing a scientific and systematic approach, key insight can be gained into determining the nature of decision support and training needed to foster higher level performance. A sound understanding of physicians' cognitive processes has the potential of providing an important basis for the development of medical systems.

References

1. Patel VL, Groen GJ. The representation of medical information in novices, intermediates, and experts. Proceedings of MEDINFO'92. 1992; 1344-1349.
2. Blois MS, Shortliffe EH. The computer meets medicine: Emergence of a discipline. In E. Shortliffe, L. Fagan (Eds.) Medical informatics: Computer applications in health care, New York: Addison-Wesley Pub. 1990.
3. Leprohon J, Patel VL. (in press). Decision making strategies for telephone triage in emergency medicine. Medical Decision Making.
4. Noble D. A model to support development of situation assessment aids. In G. Klein, J. Orasanu, R. Calderwood, C. Zsambok (Eds.) , Decision making in action: Models and methods. Norwood, NJ: Ablex Publishing Company, 1993.
5. Klein GA. A recognition-primed decision (RPD) model of rapid decision making. In G. Klein, J. Orasanu, R. Calderwood, C. Zsambok (Eds.), Decision making in action: Models and methods. Norwood, NJ: Ablex Publishing Company, 1993.
6. Patel VL, Arocha J, Kaufman D. Diagnostic reasoning and medical expertise. The Psychology of Learning and Motivation. 1994; 31:187-252.
7. Patel VL, Kushniruk A. Small worlds: Their role in the development of medical expertise. 33rd Annual Meeting of The Psychonomic Society, St. Louis, MI., 1992; 265.
8. Klein GA, Calderwood R. Decision models: Some lessons from the field. IEEE Trans. Systems, Man, and Cybernetics. 1991; 21(5): 1018-1026.
9. Ericsson KA, Smith J. Prospects and limits of the empirical study of expertise: An introduction. In K. A. Ericsson and J. Smith (Eds.) Toward a general theory of expertise. New York: Cambridge University Press, 1991.
10. Shortliffe EH. The adolescence of AI in medicine:Will the field come of age in the '90s?, AI in Medicine, 1993; 5:93-106.
11. Timpka T, Rauch E, Nyce, JM. Towards productive knowledge-based systems in clinical organizations: A methods approach, AI in Medicine. 1994; 6:501-519.
12. Heatherfield HA, Wyat J. Philosophies for the design and development of clinical decision support systems. Meth. Inf. Med. 1993; 32:1-8.
13. van der Lei J, van der Does E, Man AJ. Response of general practitioners to computer-generated critiques of hypertension therapy. Meth. Inf. Med., 1993; 32, 146-153.
14. Patel VL, Kushniruk AW. Cognition and knowledge representation in health informatics. Canadian Medical Informatics. 1994; 1:50-51.
15. Kuipers B, Moskowitz AJ, Kassirer JP. Critical decisions under uncertainty: Representation and structure. Cognitive Science, 1988;12:177-210.
16. Elstein AS, Holzman GB, Belzer LJ, Ellis RD. Hormonal replacement therapy: Analysis of clinical strategies used by residents. Medical Decision Making. 1992;12(4):265-273.