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Methodological Review

Identifying reasoning strategies in medical decision making: A methodological guide

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Abstract

Reasoning strategies are a key component in many medical tasks, including decision making, clinical problem solving, and understanding of medical texts. Identification of reasoning strategies used by clinicians may prove critical to the optimal design of decision support systems. This paper presents a formal method of cognitive-semantic analysis for the identification and characterization of reasoning strategies deployed in medical tasks and demonstrates its use through specific examples. Although semantic analysis was originally developed in the investigation of knowledge structures, it can also be applied to identify the reasoning and decision processes used by physicians and medical trainees in clinical tasks. Assumptions underlying the methods, as well as illustrations of their use in diagnostic explanation tasks, are presented. We discuss semantic analysis in the context of the current interests in developing medical ontologies and argue that a frame-based propositional analytic methodology can provide a systematic way of addressing the construction of such ontologies. Although the application of propositional analysis methods has some limitations, we show how such limitations are being addressed and present some examples of information tools that have been developed to ease, and make more systematic, the process of analysis.

Keywords: Clinical reasoning; Semantic networks; Diagnostic problem solving; Medical decision making; Explanation tasks; Explanatory coherence; Information technology

1. Introduction

Clinical reasoning in medicine has been amply studied since the 1950s. From the beginning, diverse models of reasoning in medicine have been proposed. Such models have evolved from relatively simple associational models [1], linking signs and symptoms with diagnostic categories, to more elaborate structures that include deduction, causal reasoning, and analogy making [2,3]. The complexity of clinical reasoning has been demonstrated by studies covering diverse medical tasks, including decision making [4–7], identification of medical errors [8–12], and comprehension of clinical information [8,13–15]. These studies have shown that the types of reasoning and strategies vary among clinicians; especially as a function of expertise [16], knowledge [17], and problem difficulty [18]. One question that has arisen is how to capture such complexity. In artificial intelligence, methods of representing clinical reasoning have been developed and used in the design of decision support systems. These include production rules, Bayesian probabilistic methods, case-based reasoners, and decision tables, among others [1]. Similarly, cognitive methods of representation that uncover some of the actual complexities of clinicians' reasoning have been

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developed [19–21] and tested in the analysis of medical text [22–24], clinical guideline comprehension [25,26], problem solving [27,28], decision making by health care professionals [26,29,30], translation of text and diagrammatic guidelines into computer interpretable representations [25,31], interpretation of errors in medication instructions [15], and reasoning in problem-based discussion groups [32].

The complexity of medical reasoning has also been recognized in cognitive/epistemological models [2,3], where the diagnostic process has been characterized in terms of four types of inferences: abstraction, abduction, deduction, and induction, seems to account for all aspects involved in diagnostic reasoning. The first two inference types drive hypothesis generation while latter two types drive hypothesis testing. During abstraction, data are filtered according to their relevance for the problem solution and chunked in schemas representing an abstract description of the problem at hand (e.g., abstracting that an adult male with hemoglobin concentration less than 14 d/gl is an anemic patient). Following this, hypotheses that could account for the current situation are related through a process of abduction, characterized by a ''backward flow'' of inferences across a chain of directed relations which identify those initial conditions from which the current abstract representation of the problem originates. This provides tentative solutions to the problem at hand by way of hypotheses. For example, knowing that disease A will cause symptom b, abduction will try to identify the explanation for b, while deduction will forecast that a patient affected by disease A will manifest symptom b: both inferences are using the same relation along two different directions [2]. In the testing phase, hypotheses are incrementally tested according to their ability to account for the whole problem, where deduction serves to build up the possible world described by the consequences of each hypothesis. As predictions are derived from hypotheses, they are matched to the case through a process of induction, where a prediction generated from a hypothesis can be matched with one specific aspect of the patient problem. The major feature of induction is, therefore, the ability to rule out those hypotheses whose expected consequences turn out to be not in agreement with the patient problem. This is because there is no logical way to confirm a hypothesis: we can only disconfirm it in the presence of inconsistent evidence. This evaluation process closes the testing phase of the diagnostic cycle. Moreover, it determines which information is needed in order to discriminate among hypotheses and hence which information has to be collected.

In this paper, we present a review of these cognitive methods for the analysis of clinical reasoning that have been developed in the study of medical cognition. We show how such methods capture the essential features of the medical processes underlying diagnostic tasks and how they can have implications for the design of medical decision support systems. We argue that application of methods for the representation of clinical reasoning as used by clinicians may become an important consideration in the design of decision support tools that match the clinicians' decision processes. In the following sections, we present a brief description of the tasks that are used to elicit clinical reasoning and the cognitive and ontological assumptions underlying such tasks. Next, we present the basic methodology and the types of information that can be gathered using the methods in the investigation of medical reasoning. Following, we describe the empirical paradigm to investigate and analyze reasoning in medical tasks, with specific examples of the analyses of complex clinical cases. Finally, we discuss some implications of the cognitive methods to the study of decision-making and provide a glimpse of future research.

2. Theoretical assumptions in medical cognition

In 1986, Patel and Groen [16] presented a methodology for the investigation of reasoning and problem solving in medicine. Such methodology, propositional analysis, was based on a theoretical understanding of medical case comprehension [33], which, at the time was novel to be used in a complex domain such as medicine. The interesting aspect of the method was that it attempted to unite research areas that were thought to be unrelated, namely, comprehension, problem solving, and diagnostic reasoning. Medical artificial intelligence was devoted to an examination of clinical problem solving using computational methods [34], such as rule-based representations, to characterize signs, symptoms, and diagnoses, when the use of propositional analysis allowed the representation of knowledge needed in clinical tasks, and provided a complementary methodology to the methods based on production rules. Patel and Groen's aim was to isolate the reasoning process that physicians go through when diagnosing a clinical case, using techniques to identify knowledge structures. Their research was motivated by two sets of findings. The first finding was that experts in domains outside medicine reasoned from the problem data toward a hypothesis that accounted for the data. The studies in medicine pointed to a different kind of reasoning by physicians: reasoning from a hypothesis to account for the case data, which seemed anomalous when compared to other domains [35]. The second finding was that pure problem solving response protocols, where a subject is simply asked to ''think aloud'' as he or she makes a diagnosis, tended to yield unsatisfactory or excessively sparse information regarding the knowledge being used [23]. Hence, different methods of data gathering and analysis were tried that appear to solve both the contradictions