

De ontwikkeling van medische expertise : een cognitief-psychologische benadering

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SUMMARY

Medical expertise is a subject of interest for clinical teachers. What makes a person an expert in this domain, and what is the best way to prepare students to become an expert? Naive opinions hold that medical expertise is associated with knowledge, experience, and good (that is quick, efficient and straight forward) problem solving. Until recently medical teachers and investigators in this domain believed that differences in problem-solving skills determined whether or not someone was an expert. However, both research into medical education and into human cognition have shown that this is no fruitful approach. Therefore the focus of attention has shifted toward differences in knowledge characteristics between persons of contrasting levels of expertise pertaining to differences in problem-solving. In this approach the concept 'internal representation' or 'problem representation' plays a pivotal role. Relevant problem information is selected and elaborated on, applying general or specific knowledge. The internal representation constitutes both selected and inferred information as well as activated knowledge.

The general research question of this dissertation 'What is medical expertise?' can be reformulated into two subquestions: 'What characterizes the knowledge of the medical expert as compared with novices and intermediates?' and 'How does the developmental process take place?'. In the first chapter these questions are further investigated and positioned in a historical context. In the same chapter the empirical methods that can be applied in this kind of research are described.

In Chapter 2 the first experiment is presented. In this study a free recall method was utilized to investigate the internal representation of a clinical case. Sixty-four subjects differing in level of expertise (second year, fourth year and fifth year students and family physicians) participated. This experiment showed that an increasing level of expertise is associated with better diagnostic performance. Furthermore, in the first stages of the development of expertise, the amount of represented case items increases, whereas in the later stages these items are better integrated and are represented in a more coherent way. The results suggest that the more experienced subjects select relevant information better, and finally it was shown

that higher levels of expertise are associated with a faster representation rate.

In Chapter 3 this last result was taken as a starting point to investigate whether differences in knowledge structure underlie the observed differences in internal representation and diagnostic performance.

Both Anderson (1983) and Norman and Rumelhart (1978) suppose that expertise is attained by applying the learned concepts. Knowledge application causes a structural change: long search paths are shortened and general knowledge becomes specialized. This process is called 'compilation' (Anderson, 1983). Due to these structural changes, expert knowledge application is very quick and automatic when diagnosing a clinical case. Novices and intermediates, however, apply their knowledge actively, laboriously and consciously while reasoning about a case.

If this developmental process is indeed taking place, then a drastic restriction of the available reading time will have substantial consequences on the novices' and intermediates' problem representation, whereas the experts' representation will scarcely suffer. In Experiment 2 this prediction was tested and confirmed by the data. One hundred and twenty subjects participated in this experiment: lay people, second, fourth and sixth year medical students and internists. The experts' internal representation was not affected by a strong restriction on the allowed reading time, while the novices' and intermediates' representation was seriously hampered. The same holds for the amount of knowledge that was activated. Regardless of the amount of time available (ample, sufficient or extremely short) experts activated the same *small* amount of knowledge, whereas novices and intermediates activated much more knowledge when they had ample or sufficient time. These subjects also activated much less knowledge when there was little time allowed. Content analysis of the applied knowledge provided further evidence for the assumption that the earlier stages of a learning process in a domain are characterized by the accumulation of knowledge with compilation following later.

Chapter 4 concerns the question of how medical expert knowledge is represented. The medical domain is characterized by a wide variety of diseases which can be presented to a doctor in many different ways and which may take many different courses. In order to account for the extreme adaptability of physician performance, the knowledge clusters that result from the compilation process must be enriched with knowledge concerning the patient characteristics that are associated with catching a disease, with the numerous ways a disease may manifest itself in a patient and with the incidence in different (sub)populations.

Feltovich and Barrows' model (1984) of medical expert knowledge has these characteristics. Feltovich and Barrows hypothesize that physicians when diagnosing a patient try to activate and instantiate an illness script. Such an illness script describes the conditions in the patient and his or her medical, hereditary or social background that may have contributed to the patient's present disease (the Enabling Conditions), the disease process itself (the Fault), and the signs and symptoms that are caused by the

disease and the course it may take (the Consequences). Research by Schmidt, Hobus, Patel and Boshuizen (1987) suggests that there are differences between experts and intermediates in the extent in which they rely on knowledge about Enabling Conditions in generating a plausible diagnosis. This finding supports the theory outlined above. Furthermore, Feltovich and Barrows assume that medical basic science knowledge plays an important role in the construction of the internal representation, especially when a finding in a patient deviates from what is normally found in patients with that disease.

Feltovich and Barrows' theory describes the representational format that might result from the compilation process that was hypothesized in Chapter 3 and from the enrichment and refinement of the knowledge with respect to multiple Enabling Conditions the Consequences of a Fault. There is however one element in Feltovich and Barrows' theory that diverges from the findings of the studies presented in the previous chapters. Their theory predicts that activation of an illness script causes the activation of the relevant basic science knowledge. However, Experiment 2 showed that medical experts apply far less basic science knowledge than intermediates and novices do.

In Chapter 4 two experiments are described that are designed to shed some light on these issues. Experiment 3 is a primarily explorative study with four subjects of differing levels of expertise ranging from a second year medical student to an experienced family physician. A think-aloud methodology was utilized. Its main objective was to see whether experts really apply knowledge that is richer in Enabling Conditions and more flexible in the Consequences of a disease. Both turned out to be the case. The other goal was to find out how subjects of different levels of expertise apply basic-science knowledge in representing and solving a clinical case. Contrary to the prediction that can be derived from Feltovich and Barrows' theory, it was found that in particular the less experienced subjects used basic-science knowledge

The finding that the expert in this experiment as compared with the students actually applied nearly no basic-science knowledge at all can be interpreted in three different ways:

- the expert's basic-science knowledge has become rudimentary, or
- the expert's basic-science knowledge still exists, but has become inert, or
- the expert's basic-science knowledge has become compiled and is integrated into the illness-script knowledge that is applied while representing the case, hence leaving no traces in the think-aloud protocols.

Experiment 4 was designed to investigate these three hypotheses. Twenty subjects of four levels of expertise, again ranging from second year medical students to family physicians, participated. They were asked to diagnose a clinical case while thinking aloud. Afterwards they described the pathophysiological process that underlies the case findings. These two data sets were compared. The results of this last experiment indicate that experts' basic-science knowledge has not become inert or

rudimentary but is compiled and integrated into the illness-script knowledge that is applied while thinking aloud.

Finally, in Chapter 5 the theoretical notions that are unfolded in the earlier chapters are discussed and brought together into a theory on the development of medical knowledge. These theoretical notions suppose that the development of medical expertise is characterized by several stages. In the first stage which roughly extends through the preclinical years of medical training, large amounts of knowledge are accumulated. Learning in this stage results in an elaborated knowledge base containing knowledge about the medical basic sciences and the clinical sciences. This type of knowledge is supposed to be represented in semantic networks and mental models. When the student enters the clinic and begins his or her clerkships, a new stage starts. This stage is characterized by knowledge compilation, enrichment and refinement. The knowledge resulting from these structural changes is conjectured to be dually represented: in illness scripts and in semantic nets and mental models. Both layers are presumed to be integrated, resulting in a knowledge base that allows for a flexible application of that knowledge.

The results of the experiments presented indicate that illness scripts do not originate solely from knowledge compilation and enrichment. Even the younger students seem to apply rudimentary illness scripts while diagnosing a case. The learning process rather seems to start at both knowledge layers at the same time, but with changing emphases. Finally in the expert stage, medical basic-science knowledge seems to be compiled and integrated into illness-script knowledge.

Further analyses showed that the theory lacks a representational format to represent to memory traces of the patients who were in the past diagnosed and treated by the student or the physician. Research by Norman et al. (1988) suggests that these memory traces are a powerful tool in diagnosing a new patient.

The model of medical expert knowledge that finally is presented in this chapter consists of three interrelated knowledge layers: knowledge about the medical basic sciences, represented in semantic networks and mental models; knowledge about diseases, the conditions enabling the acquisition of a disease and the associated signs and symptoms, represented in illness scripts; and the memories about former patients, represented in episodic memory traces.

A student who has the task to acquire such a complicated knowledge base runs the risk of overemphasizing one aspect at the cost of another. Especially in the clinical phase of medical education a student may concentrate on illness-script knowledge neglecting basic sciences, which may result in undesirable effects pertaining to the amount of basic-science knowledge and the integration of basic sciences into illness scripts. The chapter ends with several suggestions on how to prevent this learning style, derived from Collins et al. (in press) cognitive apprenticeship teaching model.