

Cognitive metaphors of expertise and knowledge: prospects and limitations for medical education

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CONTEXT Many approaches to the study of expertise in medical education have their roots most strongly established in the traditional cognitive psychology literature. As such, they take a common approach to the construction of expertise and frame their questions in a common way. This paper reflects on a few of the paradigmatic assumptions that have 'come along for the ride' with the traditional cognitive approach, and explores what might have been left out as a consequence.

METHODS We examine the operational definition of 'expert' as it has evolved using the traditional cognitive paradigm and we explore some alternative definitions and constructions of expert performance that have arisen in parallel education research paradigms. We address 3 inter-related aspects of expertise as manifested in the traditional cognitive approach: the construction of the expert as a (routine) diagnostician; the construction of the developmental process as the (automatic and unreflective) accrual of resources through experience, and the construction of accrued knowledge as a relatively static resource that is subsequently used and built upon with further experience.

CONCLUSIONS We hope that, by highlighting these issues, we may begin to marry the strengths of the traditional cognitive paradigm with the strengths of these other paradigms and expand the scope of cognitive research in medical expertise.

KEYWORDS *clinical competence; *cognition; *diagnosis; *education, medical; *research; knowledge.

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INTRODUCTION

The study of medical expertise has been a focus for medical education researchers for several decades. The purported value of this research enterprise appears self-evident. If we can understand the nature of expert performance and its development in individual practitioners, we will be able to structure our training programmes towards more efficient and effective development of experts and will also be able to present information to practising doctors in ways that would enable them to use their medical expertise more effectively. As the articles in this theme issue attest, this research has been informed by a variety of frameworks and approaches. However, also as evidenced by these articles, 1 of the more dominant frameworks has borrowed from the theories and methods of cognitive psychology. Against the backdrop of this traditional cognitive paradigm, efforts to understand the development and maintenance of expert doctor performance have tended to emphasise the phenomenon of clinical reasoning, and more specifically, the resources that doctors use to diagnose disease. In particular, researchers have sought to understand what it is in the expert doctor's mental processing that distinguishes expert diagnostic performance from that of a novice.

Through this lens of inquiry, a variety of interesting (often counter-intuitive) phenomena have been identified, which have shaped our understanding of expert performance in medicine. Many of these findings and phenomena, and the associated metaphors for what might therefore go on in expert mental processing, are presented in the articles contained in this issue, so we will not enumerate

Overview

What is already known on this subject

Cognitively based research in medical expertise has led to interesting and valuable inquiries regarding the nature and use of knowledge among experienced practitioners.

What this study adds

This study examines an operational definition of expertise as it has evolved using a traditional, cognitively based research approach, and explores alternative definitions and constructions of expert performance from parallel education research paradigms.

Suggestions for further research

Future research might include experimental designs incorporating alternative definitions and constructions of expert performance into our evaluation and testing of expertise. Adding this knowledge to existing understanding of ways in which experts make use of their knowledge in diagnostic reasoning tasks would enrich the cognitive medical expertise research paradigm.

them here. The overarching interpretation of these findings, however, might best be summarised with 4 important conclusions. Firstly, expertise takes years to attain and is acquired through deliberate practice in a particular domain.¹ Secondly, with this extensive experience and practice comes a set of impressively rich and well organised resources and processes with which experts are able to effectively and efficiently solve routine problems of practice. The various constructions of these resources have included prototypes,² scripts,³ encapsulated concepts,⁴ instances,⁵ semantic networks,⁶ semantic axes⁷ and probability matrices.⁸ Constructions of expert processes have been variously described as heuristics,⁹ reasoning strategies,¹⁰ restricted searches¹¹ and pattern recognition.¹² By virtue of this range of descriptions and constructions, a third general conclusion must be that the use of these resources by experts is remarkably flexible, not only for the effective diagnosis of various disease presentations, but also for the

effective completion of the variety of tasks that we as researchers ask them to perform in the context of our research studies (such as generating probability matrices⁸ or making relative similarity judgements about a set of concepts printed on cards⁶). As Custers *et al.* have suggested, it appears that whatever unnatural task we as researchers can think up for experts to do, they seem to be able to adapt their cognitive resources sufficiently to do it better than novices.¹³ Finally, it is clearly apparent from reading this literature that the specific nature of each expert's individual set of resources and processes is remarkably idiosyncratic,¹⁴⁻¹⁷ probably because of the idiosyncratic nature of each expert's personal experience and practice.

More recently, in an effort to capture the dynamic nature of medical expertise, cognitively based research has focused not on what resources are contained in an expert's mental processing, but, rather, on how these resources are used in concert during daily practice. As a manifestation of this effort, some researchers have focused on the co-ordination of analytic and non-analytic resources as a function of task.^{18,19} One of the most systematic programmes of research in this area is summarised in the article by Eva *et al.* in this issue. As a second manifestation of this question of resource co-ordination, research groups have begun to explore this phenomenon more in terms of a shifting reliance on the automatic and deliberative use of resources from moment to moment in daily practice²⁰ in a self-regulatory process referred to variously as 'slowing down when you should'²¹ and 'knowing when to look it up'.²²

Although it is clear that the traditional cognitively based research paradigm in medical expertise has led to interesting and valuable inquiries regarding the nature and use of knowledge among experienced practitioners, it is important to recognise that with any paradigm come certain approaches and assumptions that narrow the focus of the research. Of course, this is the strength of a paradigmatic approach. However, if used unquestioningly, this is also a paradigm's weakness. For example, there is always the possibility that the nature of expertise has been presupposed by the methodologies that we use to understand it. This paper, therefore, will reflect on a few of the paradigmatic assumptions that have 'come along for the ride' with our traditional cognitive approach, and will explore what might have been left out as a consequence. In particular, we wish to examine the operational definition of 'expert' as it has evolved through this research. We will then explore some alternative definitions and

constructions of expert performance that have arisen in parallel education research paradigms.²³ We will address 3 inter-related aspects of expertise as manifested in the traditional cognitive paradigm:

- 1 the construction of the expert as a (routine) diagnostician;
- 2 the construction of the developmental process as the (automatic and unreflective) accrual of resources through experience, and
- 3 the construction of accrued knowledge as a relatively static resource in the expert's mental processing that is subsequently used and built upon with further experience.

We hope that, by highlighting these issues, we may begin to marry the strengths of the traditional cognitive paradigm with the strengths of these other paradigms and expand the scope of cognitive research in medical expertise.

THE NATURE OF EXPERTISE IN DAILY PRACTICE

Although it is probably generally acknowledged and relatively uncontroversial that expertise, in its broadest sense, is a multi-faceted construct, the operational definition of expert performance in the context of medical education research tends to be functionally related to more routine diagnostic activities. Recognising that medical experts use their mastery of the domain to accurately diagnose patients, studies on expertise in the traditional cognitive framework have focused on the ways in which experts and novices differ in their efforts to solve diagnostic problems in which experts are usually quite accurate. Even in studies where participants are asked to engage in tasks well outside the usual activities of daily practice (such as card-sorting tasks or the generation of probability matrices), these studies tend to focus on the outputs of the task (as metaphorical windows on experts' versus novices' knowledge structures) rather than on the creative processes involved in completing them. As a result, research within this paradigm has tended to constrain experts to working well below their limits of ability and to using their knowledge in a highly constrained manner.

This approach to studying the nature of expertise contrasts interestingly with studies in other paradigms where experts are pushed to extend themselves by working 'at the edges of their competence'. In such situations, it has been found that only some

'experts' go beyond routine competencies and display flexible, innovative abilities within their domain in a process of 'extending their knowledge rather than applying it'.²⁴ Such findings have led researchers in these other domains to draw important distinctions between 'adaptive expertise' and 'routine expertise'^{24,25} or between 'experts' and 'experienced non-experts'.²⁶ Routine experts (or experienced non-experts) are highly skilled technicians within their domain. They have learned complex and sophisticated sets of routines and apply them effectively and efficiently in their practice. However, when faced with a novel problem, they will tend to continue to use their existing routines, trying to adapt the problem to the solutions they are comfortable with rather than adapting their solutions to the novel problem. Both because of, and as a result of this approach to practice, additional learning tends to focus on improving efficiency by refining specific aspects of established routines. By contrast, adaptive experts will use a new problem as a 'point for departure and exploration'.²⁴ They consistently seek problems and challenges that stretch the boundaries of their knowledge and competency. New problems are seen as opportunities to 'explore and expand their current levels of expertise'.²⁴ Thus, adaptive experts are characterised by their 'flexible, innovative and creative competencies within the domain rather than in terms of speed, accuracy and automaticity of solving familiar problems'.²⁵ They don't 'attempt to do the same things more efficiently; they attempt to do them better'.²⁴

The identification of distinct types of expertise as described in these literatures leads to a potentially troubling conclusion with regard to the cognitive paradigm. The traditional cognitive research emphasis on identifying differences in performance across levels of experience has overlooked important distinctions between types of expertise among individuals with similar levels of experience. Such distinctions, largely obscured by our cognitively based programmes of research, may have important implications for our understanding of excellence and our construction of educational programmes intended to achieve it. This issue will be further elaborated in the next section.

THE DEVELOPMENT OF EXPERTISE

As with the definition of expertise itself, there may be an important assumption implicit in how we, as researchers into the cognitive base of medical

expertise, operationalise the process of developing expertise. That is, our cognitive studies, which tend to examine how novices differ from experienced practitioners in performance, are generally grounded in the operational assumption that (with the odd exception) most novices eventually become experts. It is presumed that with more experience comes the accrual of a greater (or better) resource base on which to rely, suggesting that expertise is an automatic and inevitable consequence of experience. The focus therefore, is on what has been acquired through that experience and the educational consequences are couched in questions about how to get these resources into novices faster or more efficiently.

Again, however, the literatures that draw distinctions between routine and adaptive expertise raise concerns regarding this construction of expert development. Consistent with the idea that there are different kinds of expertise (not just different levels), researchers in this paradigm have proposed that routine and adaptive expertise have distinct developmental pathways^{24,27,28} that are distinguished by one's approach to daily practice. Unlike routine expertise, adaptive expertise is not merely the accrual of resources and skills through experience and practice. In fact, it has been argued that, as individuals acquire the knowledge and experience to solve typical problems, they establish routines that may work against their further growth.²⁹ The mark of adaptive expert development and the form of learning and practice associated with it, therefore, involves an inherent understanding of the assumptive nature of these routines. Adaptive experts continue to grow only because of their intentional engagement in 'progressive problem solving', that is, the continual reinvestment of cognitive resources into creating not merely better performance, but, in fact, better understanding of the problems of their domain.²⁶ The development of adaptive expertise, therefore, is not a simply a process of acquiring knowledge and skills in a domain, but, rather, it is an active process of challenging and thereby transforming one's knowledge and skills in a domain.

An important consequence of adopting the adaptive expert developmental pathway is the development of the ability not only to master the knowledge of a particular domain but also to make innovative contributions to the domain through a process of knowledge building that commences from the beginning of one's training.³⁰ Within the traditional cognitive paradigm, 1 approach to understanding the place of innovation in any domain has been to examine 'eminent achievement',¹ which supposes

that certain individuals display a combination of knowledge (acquired through deliberate practice) and natural ability that makes them 'grand experts' capable of extraordinary performances and contributions to their field. However, such an approach rarifies these individuals and renders them less interesting to educators. Researchers outside the traditional cognitive paradigm have, instead, focused on trying to understand the types of contexts and experiences that lead to the development of adaptive experts, capable of building and creating new knowledge in their fields. This approach characterises adaptive expertise as an acquired approach to practice rather than as an innate ability and seeks to provide learning environments that foster the development of the competencies underlying adaptive expertise.^{28,31,32} In this construction then, the practice of expertise is a dynamic and ongoing process. It refers to not only the development and use of a repository of knowledge in the intellect, but also the way by which the expert creates and uses knowledge in the world.

Of course, the research approach described above moves us well outside the traditional cognitive paradigm, and it is not our intention to suggest that this is the 'right' way to study adaptive expertise. Nonetheless, if we are to take this construction of adaptive expertise seriously, we cannot expect that the underlying structures and processes of routine expertise will be predictive of adaptive expertise, nor that diagnostic excellence on routine problems of practice can inform us about the processes underlying adaptive expertise. To date, as a result of the emphasis on expert–novice differences, it is likely that the traditional cognitively based studies of medical expertise have revealed more about routine expertise than adaptive expertise and have led to educational models for equipping our novices with more intellectual resources faster. Approaches to understanding the nature of adaptive expertise might be valuably incorporated into our designs and research questions.

THE CONSTRUCTION OF KNOWLEDGE RESOURCES

A third implicit assumption built into the traditional cognitive paradigm of medical expertise research involves the nature of the accrued resources themselves. That is, asking about the components of an expert's mental processing tends to lead to a treatment of the knowledge gained from previous

experience as something that is acquired, stored and called upon to address future problems of practice. Consistent with a 'folk psychology' metaphor of the mind as a container, our research paradigm has come to understand expert performance as the outcome of experts applying their intellectual knowledge to their daily work. Because the knowledge is implicit in the work that is being performed, watching experts perform at particular time-points in our studies was thought to reveal the knowledge they possessed.

While this may be a reasonable assumption, it carries within it the possibility of treating knowledge solely as a stable and therefore relatively static resource that experts are able to call upon in their daily practice. This, in turn, can lead to a construction of experience as primarily adding to knowledge (or at best incrementally refining it) rather than transforming knowledge. Among the more salient realisations of this potential concern is the construction of our studies as having 'learning phases' followed by 'test phases'; this is explicitly enshrined in the title of a cognitive psychology paper³³ that has formed the basis for several subsequent studies on the expert co-ordination of analytic and non-analytic resources in the medical education literature:^{18,19} 'After the learning is over: factors controlling the selective application of general and particular knowledge.'

This slippery slope to treating experience, once accrued, as a relatively static resource in memory has some interesting implications. For example, it implies that with experience, experts know more than, but do not know differently, from novices. In medical education, a manifestation of this has been a response to the recognition of context specificity in clinical reasoning. A sensible educational strategy that arises from the 'more resources' construction of expertise would be to ensure that novices get as many diverse experiences of each disease as possible in as many contexts as possible as quickly as possible in order to build an wide database of knowledge, enabling them to cope analogously with the future variance and vagaries of their anticipated clinical environment.³⁴ We do not have to look far to see conceptual inconsistencies with this approach: for example, Bordage³⁵ showed that in the early stages of learning it is often fewer, rather than more, examples that lead to better learning. Needham and Begg³⁶ demonstrated that it is possible to teach for broader analogical transfer if participants are encouraged to treat the problems meaningfully as problems to be solved rather than as just examples to be learned.

Perhaps more importantly from an epistemological perspective, the treatment of expert knowledge as a set of stable, previously stored resources that are simply used and added to, probably under-represents the extent to which adaptive experts treat their own knowledge and understanding as a 'conceptual artefact' that can be articulated, shared, critiqued and iteratively improved.²⁹ In the hands of an adaptive expert, knowledge is not a static resource, and expertise is not the culmination of possessing as much domain-specific knowledge as possible. Instead, knowledge is seen as a constantly evolving, dynamic resource, and expertise resides in the ability and willingness to not only to use and build, but also to purposefully adapt and re-engineer knowledge effectively. As a result, adaptive experts view their practice not just as a means to generate desirable outcomes, but as its own form of 'knowledge in the world'.²⁹

Adopting an adaptive expert approach to the construction of knowledge does not deny the value of extensive experience as a resource for effective performance. It is undeniable that the amount of knowledge that an expert possesses is crucial to the enactment of expertise. However, narrowing the construction of expertise to the resources accrued in an expert's intellect limits our conception of what an expert can do, affects the ways in which we evaluate and teach future experts and may even impact the way that experienced practitioners themselves believe they should perform.²⁴ By contrast, if we find ways to incorporate the construction of adaptive expertise in our paradigm, rather than encouraging our students to solve new cases solely through recourse to past experience (admittedly an important and valuable strategy), we might additionally focus on the ways in which they can use new cases to change their understanding and construction of that past experience. We are not suggesting that expert practitioners should constantly engage in the process of building knowledge and evolving their practice, but a conception of expertise that explicitly excludes these skills has consequences for the medical profession. By definition, adaptive experts never believe the learning is over and act accordingly when appropriate.

DISCUSSION

Within the traditional cognitive paradigm, expertise has been defined broadly as the mastery of existing knowledge and techniques in a given domain.³⁷ In medical education research, questions about how this mastery is most effectively attained, and what is

involved in the expert's intellectual resources by the time it is, have produced some interesting and important findings that have shaped the way we think about experts. However, implicit in this definition is the possibility of constructing expertise as an end state of 'complete' knowledge that evolves, at best, only as the existing knowledge and techniques of the domain evolve. Perhaps it is sensible to consider routine expertise as the accrual of resources that enable the rapid and uncomplicated solution to typical problems. However, we would argue that adaptive expertise is not a state of accomplishment, but rather is best thought of as an *approach to practice*, an ongoing process of continual reinvestment of cognitive resources in an effort to transform practice and extend the boundaries of knowledge and technique iteratively. Again, this is not to deny the crucial role of experience and knowledge in defining the clinical expert. But it does imply that adaptive expertise is not a developmental stage beyond routine expertise. Rather, it is a set of habits that must be acquired and continuously enacted from the beginning of training. As Aldous Huxley wrote: 'Experience is not what happens to a man; it is what a man does with what happens to him.'³⁸

To an important degree, much of the cognitively based research on expertise in medical education has implicitly adopted the more restricted definition of expertise as routine expertise in the 'controlled' experimental designs we have created to study it and the outcome measures we have used to test it. In our decisions to compare levels of experience and equate these with levels of expertise, in our decisions to remove participants from their usual contexts (violating our own tenets of context specificity), in our decisions about the nature of the tasks we ask them to perform, and in our decision to uncover the expert's intellectual resources, we have run the risk of narrowing the definition of expertise to performance of the mundane.

Although such a narrow definition may not be inappropriate in the purely theoretical laboratories of psychology departments, in an applied domain such as medical education, where researchers and educators live side by side, it is inevitable that our constructions of expertise will have a strong impact on pedagogical models for medical education. The ways in which we operationalise expert knowledge and behaviour become the benchmarks for our training and practice. Thus, it is particularly important for us to ensure that our methodologies and constructions of expertise properly reflect the competencies we want to foster in our experts.

Studies of expertise that exclusively examine the performance of routine expertise in diagnostic problems therefore run the risk of leading us to aim uncomfortably low in our curricular objectives.

What would this type of inclusion mean for our research questions and methodologies? One possible suggestion is that we might develop experimental designs that incorporate the distinction between routine and adaptive expertise into the selection of participants and into the tasks we use to evaluate and test expertise. This would move us away from diagnostic reasoning tasks that assess expert–novice differences and towards researching participants both across and within levels of experience on tasks that elicit more than routine diagnostic problem solving. Adding this knowledge to our existing understanding of the ways in which experts make use of their knowledge on diagnostic reasoning tasks would enrich the cognitive medical expertise research paradigm. In this way, a more comprehensive programme of research on medical expertise might develop and inform our medical education programmes, thereby helping to produce better and more adaptive expert practitioners rather than simply producing routine experts more efficiently and effectively.

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