

SPECIAL CONTRIBUTION

Diagnostic reasoning and cognitive error in emergency medicine: Implications for teaching and learning

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Abstract

Background: Accurate diagnosis in emergency medicine (EM) is high stakes and challenging. Research into physicians' clinical reasoning has been ongoing since the late 1970s. The dual-process theory has established itself as a valid model, including in EM. It is based on the distinction between two information-processing systems. System 1 rapidly generates one or more diagnostic hypotheses almost instantaneously, driven by experiential knowledge, while System 2 proceeds more slowly and analytically, applying formal rules to arrive at a final diagnosis.

Methods: We reviewed the literature on dual-process theory in the fields of cognitive science, medical education and emergency medicine.

Results and Conclusion: The literature reflects two prominent interpretations regarding the relationship between the fast and slow phases and these interpretations carry very different implications for the training of clinical learners. One interpretation, prominent in the EM community, presents it as a "check-and-balance" framework in which most diagnostic error is caused by cognitive biases originating within System 1. As a result, EM residents are frequently advised to deploy analytical (System 2) strategies to correct such biases. However, such teaching approaches are not supported by research into the nature of diagnostic reasoning. An alternative interpretation assumes a harmonious relationship between Systems 1 and 2 in which both fast and slow processes are driven by underlying knowledge that conditions performance and the occurrence of errors. Educational strategies corresponding to this alternative have not been explored in the EM literature. In this paper, we offer proposals for improving the teaching and learning of diagnostic reasoning by EM residents.

INTRODUCTION

Researchers have been interested in how physicians diagnose since the early 1970s.^{1,2} For good reason: the cost of misdiagnosis is very high, from the standpoint of both clinician training and patient care. Emergency medicine (EM) is one of the specialties with the highest

diagnostic frequency of diagnostic errors.³⁻⁵ Up to one in five diagnoses may be incorrect.⁶

Diagnosis in EM is associated with many challenges linked to the specificities of the practice environment, including the simultaneous management of multiple patients, the need to act rapidly in a context of uncertainty, and reasoning with often incomplete and

Supervising Editor: Brandon C. Maughan

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partial information.^{4,5} Correspondingly, enhancing and accelerating the development of diagnostic expertise constitutes a priority in the education of emergency clinicians within the context of residency training.⁷ However, strategies for teaching and learning clinical reasoning as well as the approach to diagnostic error need to be guided by relevant principles of learning and expertise derived from research in cognitive psychology.

This paper will first summarize the current state of research on diagnostic reasoning, according to the dual-process theory (DPT). Readers interested in a more complete review are referred to a recently published reconceptualization of DPT.⁸ We emphasize the universal recognition of two cognitive processes (i.e., intuitive and analytical) of information processing in diagnostic reasoning. We will then contrast two interpretations of DPT with respect to the hypothesized mechanism of diagnostic error. A process-based model, according to which errors are predominantly attributed to biases occurring at the intuitive step and requiring analytic reasoning to be corrected, is prominent in the EM literature and in some reports.^{3,9} An alternative, knowledge-based interpretation recognizes that knowledge is the key to understanding diagnostic reasoning and the main explanatory factor of diagnostic errors. We will then show that the second approach, although less prominent in EM education circles, is well grounded in the cognitive science literature and supported by education research. We suggest that it provides the basis for a compelling alternative approach to teaching EM diagnosis. We will offer several teaching strategies reflecting this synergistic vision of DPT.

TWO CONCEPTS OF FAST AND SLOW

DPT has been adopted as a model of thinking in many disciplines^{10,11} and is prominent in discussions of diagnostic reasoning in EM. It recognizes two cognitive processes operating in the context of diagnostic reasoning.¹²⁻¹⁴ System 1 involves rapid recognition and retrieval of diagnostic hypotheses. Sometimes simplistically referred to as “pattern recognition” it is based on immediate recognition of a potential diagnosis through activation of experiential knowledge. System 1 operates below threshold of consciousness so is commonly described as intuitive. It expedites decision making by directly retrieving a solution from memory and avoiding the need for the systematic analysis of the situation.¹⁵ A second, slower process, referred to as System 2, is characterized by the analytical, conscious, application of formal knowledge to a diagnostic problem, invoked when a possible solution is not evident.¹³ The concurrent working of these two systems of cognition is well supported by empirical and experimental evidence.^{10,11} Abundant research on multiple levels supports the general validity of the DPT model and work carried out in the field of EM has shown that the reasoning of emergency physicians is in line with this theoretical model.⁵

Of the two main interpretations of the DPT construct, the one that figures most prominently within the EM literature is nonsynergistic. Within this view, the fast and slow domains of diagnostic reasoning are conceived of as working independently of each other

and frequently in an antagonistic fashion. Errors are thought to arise as a consequence of cognitive biases present in System 1 and are corrected by rational logical thinking exemplified in System 2. Based on this conceptualization, emergency physicians and residents are encouraged to recognize error-producing biases originating from System 1 mobilization and to correct them through exercise of the analytical processes inherent in System 2.^{3,16,17}

The alternative, synergistic vision of DPT, with roots in literature extending back over 30 years,^{8,18} sees the functioning of System 1 and System 2 processes as underpinned by a process of recognition. Within this model, System 1 corresponds to immediate recognition of a solution based upon prior case experience supported by clinical knowledge, while System 2 reflects an analytical process of recall of quasi-algorithmic procedures, also based on background knowledge and is invoked when no workable solutions are evident. System 1 is always the starting point for reasoning, as it enables hypotheses to be generated, even by novices. However, for the latter, the lack of specificity of solutions and the more frequent errors in these solutions will require the mobilization of rules and algorithms that place heavy demands on System 2. Over time, as case experience expands, the System 1 hypotheses are generated by knowledge that is increasingly richer and better organized in long-term memory, and System 2 is relegated to a function of confirming the diagnosis. In this view, the two cognitive domains work in tandem with each other.^{8,14,18} It also leads, as we shall see, to very different implications regarding educational approaches and reflection on diagnostic errors.

THE GENESIS OF ERROR

The large range of possible diagnoses in EM practice, combined with time pressure and information gaps, makes this environment particularly conducive to the occurrence of errors.³ The two interpretations of DPT correspond to very different assumptions regarding the sources of diagnostic error, and the choice between these assumptions is central to the framing of current instructional and educational strategies we seek to address.

Blaming intuition

The current, prevalent, nonsynergistic understanding of DPT has led many authors to the following two assumptions: 1) the accuracy of intuitive (System 1) processes is less than that of analytical (System 2) processes and 2) analytical processes have the ability to detect and correct errors made by intuitive processes.^{14,19-21} Errors attributed to these assumptions are commonly referred to as biases. Dozens of cognitive biases have been described in the literature.^{20,22} Much of the work carried out on cognitive biases is part of heuristics and biases approach, which emerged in the 1970s from the premise that human judgment is particularly vulnerable to error.²³

As the main process for generating diagnostic hypotheses in EM,⁵ intuition is typically referred to as default thinking.²⁴ The assumption

that diagnostic errors arise from cognitive biases residing within System 1 thinking has led to a large literature, within and beyond EM, regarding the importance of such biases and, consequently, of debiasing strategies.^{17,25,26} In fact, empirical research has not supported either of the assumptions corresponding to the nonsynergistic model of DPT, i.e., that System 1 is the main source of error and that educational interventions would fruitfully be based on this principle.^{8,27-32} We will briefly summarize this research with emphasis on that most directly relevant to EM, before proceeding to the implications of the alternative, synergistic, interpretation of DPT.

Slowing down does not improve accuracy

Work carried out since the 1990s has shown that attempting to hinder the functioning of intuition does not lead to improved diagnostic performance.³³⁻³⁵ For example, studies designed to test strategies that provide increased time, thereby encouraging a greater reliance on analytical processes, have not demonstrated improvements in diagnostic accuracy.^{27,29,30,36,37} To the contrary, improved accuracy is associated with rapid diagnosis.^{27,38} Moreover, the time scales can be extremely short. In a recent study, residents and staff were shown ECGs and CXRs in times ranging from 175ms to 1000ms and asked to identify normal or abnormal. Accuracy was about 0.70-0.83 with only a small increase at longer times. The second study looked at diagnosis with times from 1s to 20s. While true-positive raters improved slightly with longer times, so did false-positive rates, so overall accuracy was nearly constant from 5 to 20 s.³⁹ Accurate diagnostic hypotheses emerge early in the clinical process and emergency physicians do not typically need much time to solve routine cases.^{5,30} These findings suggest that intuition is no less vulnerable to error than analytical reasoning.

Debiasing strategies do not debias

Debiasing strategies have been defined as “a deliberate, conscious selection of a particular strategy in a specific situation to optimize decision-making and avoid error.”³ Cognitive forcing strategies is an umbrella term that encompasses virtually all specific mental tools aimed at systematically eliminating the error-prone impact of cognitive biases via the enforcement of analytical oversight of the diagnostic process. They assume that a physician who has a thorough knowledge of cognitive biases, and can identify situations in which biases are likely to occur, might develop metacognitive control over their own reasoning, in real time, to avoid error.³ Such strategies can be learned by EM residents and increase their awareness of the existence of biases.⁴⁰ Unfortunately, when their effect on reducing diagnostic errors has been tested, they have proven ineffective, regardless of the specialty and level of training at which they have been applied.^{28,30,32,37,41-43} As an example, Sherbino et al.⁴² randomized senior medical students undergoing an EM rotation to case-based instruction on the use of cognitive forcing strategies and compared

their performance on a series of diagnostic vignettes to that of students who did not receive the instruction. No difference in the rate of diagnostic error was observed between the groups. Similar results were observed in other tests of cognitive forcing strategies. In another study involving EM and internal medicine residents, Sibbald et al.²⁸ and Mamede et al.⁴⁴ showed that cognitive debiasing checklists did not improve participants' performance in ECG interpretation.

Furthermore, clinicians, including experts on cognitive bias, show poor skills in identifying cognitive biases. Zwaan et al.³¹ studied the ability of physicians recruited from the Society to Improve Diagnosis in Medicine to identify biases within case scenarios involving both correct and incorrect diagnosis. They found no agreement above chance in identifying the presence or absence of individual biases. Further, when the scenario described an incorrect diagnosis in the last sentence, observers identified twice as many biases as when the correct diagnosis was present. Such observations pose a serious challenge to the assumption that cognitive biases constitute a useful construct in relationship to curtailing diagnostic error.

THE ALTERNATIVE: SPEED THE DEVELOPMENT OF EXPERIENTIAL KNOWLEDGE

Abundant literature attests to the fact that the difference between a novice and expert diagnostician is not found in superior generalized problem solving, but rather by a wide and deep base of experiential (case-based) knowledge.⁴⁵ An older attending physician does not possess superior reasoning and, in fact, fluid intelligence may be diminished, in comparison to a young medical student.⁴⁶ Rather, improved diagnostic ability by the attending physician is a function of the years of practice (and thousands of patient cases) that informs the individual's experiential knowledge.

The educational challenge is to optimize the functioning of System 1 by ensuring that practitioners acquire relevant knowledge in a way that can be retrieved as needed. Key to the development of instructional strategies is the recognition that human memory, like contemporary generative AI approaches, amounts to retrieving knowledge from memory based on similarity of associations.⁴⁷ This observation has led researchers to take an interest in the way experience helps to improve knowledge organization in long-term memory.^{1,30}

Education as facilitation of memory retrieval

We propose to adopt a framework that moves away from *process*-based approaches to learning and focuses on *knowledge*-based approaches (Table 1). In other words, it is not the cognitive processes (the “engines”) that are directly at fault in diagnostic errors but limitations in the knowledge (the “fuel”) that powers them. By “knowledge”, we do not mean only formal knowledge such as resides in textbooks and lectures and is accessed by means of deliberative, analytical strategies. Rather, we view experiential knowledge,

TABLE 1 A comparison of the process-based and knowledge-based views of the dual-process models of diagnostic reasoning.

	Process-based model	Knowledge-based model
Accurate diagnostic performance requires:	Efficient functioning of analytic information processing	Increasing experiential knowledge
Errors mainly stem from:	Fallible intuitive processes	A lack of experiential knowledge
Teachers should help students:	Learn general reasoning strategies that identify and counter cognitive biases	Expand retrievable knowledge for action from long-term memory

generated through the multitude of patient experiences acquired by a practitioner over years of clinical practice, as central to the diagnostic process.⁴⁸ Such an approach implies moving away from the nonsynergistic, process-based view of DPT toward recognition that the key to diagnostic performance lies in the nature and quality of knowledge retrieved from long-term memory, and that the key to improving diagnostic reasoning involves building operationalized and contextualized models of knowledge organization.

IMPLICATIONS FOR EDUCATION

There is substantial support in the medical education literature for fostering intuitive skills and contextualized clinical knowledge, in addition to analytical skills, in the course of facilitating diagnostic expertise.⁴⁹ However, this literature is largely directed to undergraduate medical education rather than to the special needs of EM postgraduate training. To address this gap, we offer some suggestions. **Table 2** contains recommendations specific to the clinical supervision of residents. They are based on theories of mixed practice,⁵⁰ distributed practice,⁵¹ cognitive load,⁵² and elaboration.⁵³ Recommendations are further described below and expanded to other educational settings, such as simulation sessions and case reviews during formal academic conferences or curricula. Within the latter, morbidity and mortality exercises constitute a particularly pertinent venue, where clinical errors are highlighted and system and educational solutions are suggested.

Teach EM knowledge

This statement seems tautological. However, the knowledge that is important to diagnostic accuracy will only be functional if it is integrated into organized knowledge networks, in the form of exemplars,⁵⁴ prototypes,⁵⁵ or illness scripts.⁵⁶ Knowledge without experience or application offers only moderate benefit to accurate diagnosis. It can end up unretrieved from long-term memory because the knowledge is not organized around relevant clinical stimuli. The corollary to emphasizing knowledge is to avoid emphasis

TABLE 2 Effective educational strategies for unstructured teaching in the ED.

What to do	<p>Facilitate the encounter of numerous and varied patients in the ED environment. Supplement learning via simulation.</p> <p>Associate each patient experience with specific feedback about key knowledge-based elements of the case.</p> <p>Choose one or two specific aspects of each experience to be debriefed around gaps in clinical knowledge.</p> <p>Devote part of case feedback on the initial genesis of diagnostic hypotheses, based on the first patient data encountered.</p> <p>Encourage students to make explicit the data they used to formulate, eliminate, and prioritize diagnostic hypotheses.</p>
What not to do	<p>Do not focus feedback solely on what the student has done—the observable dimension of student performance—without linking it to the reasoning of the student, and more specifically to the knowledge used to reason.</p> <p>Avoid cognitive overload and emphasis on extraneous knowledge via over teaching.</p> <p>Do not teach general reasoning or debiasing strategies.</p>

on cognitive bias and cognitive debiasing techniques, since there is no evidence supporting their educational effectiveness.

While the ED is the venue where residents learn and grow and have the opportunity to acquire and apply clinical knowledge, it is far from optimal in terms of learning the multiple exemplars that ultimately equate to clinical expertise. Ideally, residents should have the opportunity to compare and contrast cases to learn the features that differentiate between one case and another. Such situations are not naturally facilitated in a busy ED. Residents' clinical experience can and should be enhanced by confronting them with situations in which they will have to solve problems that require activation of knowledge. The learning venue may be bedside teaching and supervision of the care of real patients, but it may be more optimally derived from carefully structured exercises, small- or large-group instructional settings, and simulations. Central to this approach are two different instructional strategies that are directly based on an understanding of human associative memory and derived from experimental evidence of effectiveness.

Mixed (interleaved) practice

To learn the features that distinguish one category (diagnosis) from another, it is beneficial to have the opportunity to compare and contrast examples from different diagnostic categories. This strategy of mixing up examples from various categories has been shown to lead to dramatically increased performance. For example, Hatala et al.⁵⁷ showed that students who learned to read ECGs with mixed practice showed about 50% greater accuracy on a new test.

Distributed practice

EM postgraduate education in the United States is built around half-day academic conferences. However, as many EM programs have recognized, and has been demonstrated through research involving other specialties, there are advantages to spreading out learning over multiple shorter sessions.⁵⁸ The benefit results from improved long-term retention of knowledge, which is in turn a consequence of the extra effort needed to recall learned materials after some time has elapsed. While we are not aware of specific studies of EM diagnosis, the general and robust finding of improved knowledge retention bears consideration of this instructional strategy.

Use simulation to supplement experience; expensive technology may not be required

The purpose of fostering diagnostic skills with interleaved practice amounts to providing a heterogeneous sample of diagnoses with a common symptom presentation. Feedback is immediately provided. The goal is to allow residents to rapidly and efficiently acquire a database of patient presentations that would be less practical to achieve in the unstructured, unplanned queue of actual ED patients. Simulation holds promise to deliver ecologically representative case series in an efficient manner. It may also introduce exposure to rare, but “must-know” clinical presentations.

A natural response is that the more realistic the simulation, the better to facilitate transfer to the real world. However reasonable this assumption may be, it is incorrect. Two lines of evidence support this contention. First, Norman et al.⁵⁹ reviewed studies comparing low- and high-fidelity simulators for three domains—heart sounds, surgical skills, and critical care management and found no difference between high- and low-fidelity simulators. Similar findings have been reported by others in connection with learning contexts not specific to diagnostic skills.^{60,61} Resource constraints may limit the use of high-tech approaches to simulation, which needs to be evaluated in the context of development of EM residents' diagnostic reasoning skills.

Provide feedback on patient outcomes and foster reflective practice

Emergency physicians work in an open-loop system, in which they frequently are unaware of patients' eventual diagnosis until well after their disposition. Feedback, when available, ensures accuracy of the exemplars, prototypes and illness scripts drawn upon during the diagnostic process.¹³ To achieve this goal, feedback should focus on specific patient and clinical elements and target the moment when the student was first exposed to patient data. If the learner has missed a diagnosis that should have been made, instead of stressing the need to entertain “a very broad differential diagnosis”, help the learner identify the “singularities” of the presentation—clinical elements that did not fit the provisional diagnosis but were more

consistent with the correct final diagnosis. This approach falls within the framework of reflective practice.⁶² It is regularly presented as the main tool for experiential learning.⁶³ Teachers should avoid non-specific admonitions to reflect or the use of generic instructions (e.g., “be careful”, “consider all the data”) because they are ineffective.^{44,64} Effective reflection seeks to mobilize rarely accessed knowledge and past experience for future use.

Use many whole cases, not serial cue cases

There is a long history of using virtual patients in medical education dating back to the paper-based patient management problems of the 1960s.⁶⁵ Whether paper or computer, the common element is that the student works their way through the standard elements of a patient encounter—chief complaint, history of present illness, system review, etc.; gathering data along the way; and revising diagnoses as they go. In short, they are simulating the reasoning process. But as we have discussed, the DPT theory derives more from knowledge than any reasoning process. A focus on working through cases step by step will inevitably prolong the time spent on any particular case and ultimately limit the number of cases a student can learn in a fixed period of study.

Schmidt and Mamede⁶⁶ conducted a review of strategies used in teaching clinical reasoning. The dominant approach was the serial cue approach, and using the whole case was present in only a minority of studies. However, they concluded that “thinking process-oriented approaches were shown to be largely ineffective” in part because they overwhelmed working memory. Novices lack the necessary illness scripts to cue a differential diagnosis from the minimal information provided in the first (or subsequent) series of partial information. Instead, they were required to load working memory as information was presented, trying to remember and make connections across progressive bits of information as they were revealed in the case. Conversely, the evidence showed that the whole-case approach was effective in teaching reasoning, perhaps in part to a novice's ability to jump around a case, where all the data were present, and make connections in real-time without overwhelming working memory. Moreover, time on a whole case is less than a serial cue case, permitting increased exposure to case variety.

Protect working memory

Working memory has a fixed capacity.⁶⁷ Compared to novices, experts can automate some diagnostic tasks or chunk related sub-tasks into a larger, umbrella task. Both of these features permit the expert to process more information without overwhelming working memory and increasing cognitive load.⁶⁸ Effective education necessitates moderation of both unnecessary distractions and excessive teaching in a single encounter. In both instances, the number of stimuli to be processed exceeds the capacity of working memory and learning is impaired.⁵²

In line with this, educators should refrain from approaches to teaching that overwhelm a learner by volume of information. Bedside teaching that reverts to elaboration of extraneous knowledge, such as attention to clinical characteristics of diagnostic entities not under serious consideration, is distracting and may impede a learner to organize new knowledge with preexisting knowledge.

CONCLUSIONS

Diagnosing patients accurately and efficiently within the chaotic environment of a busy emergency department requires both intuitive and analytical skills. Expertise embodies the continued development of both cognitive domains. Given the high cost and stress of diagnostic errors to both patients and emergency clinicians, it is understandable that emergency physicians and educators would seek shortcuts, such as formulas for identification of biases, to the development of diagnostic acumen. This evidenced-informed perspective offered discourages emphasis on general problem-solving solutions to diagnostic challenges. Clinicians, learners, and educators need to recognize that increasing contextualized, experientially based clinical knowledge holds the key to enhancement of both dimensions of diagnostic skill.

We advocate for evidence-informed educational interventions to enhance and accelerate emergency medicine residents' diagnostic reasoning skills. There is also a need for more emergency medicine-specific research on the effectiveness of educational strategies. Such research needs to take into account the complex nature of emergency medicine diagnosis and the context within which it takes place.

AUTHOR CONTRIBUTIONS

All authors have jointly discussed about the structure and content of the article. Thierry Pelaccia and Jonathan Sherbino wrote a first version of the article, which was critically reviewed by the other team members. All authors approved the final version of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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How to cite this article: Pelaccia T, Sherbino J, Wyr P, Norman G. Diagnostic reasoning and cognitive error in emergency medicine: Implications for teaching and learning. *Acad Emerg Med*. 2024;00:1-7. doi:[10.1111/acem.14968](https://doi.org/10.1111/acem.14968)