Diagnostic error and clinical reasoning

Geoffrey R Norman & Kevin W Eva

CONTEXT There is a growing literature on diagnostic errors. The consensus of this literature is that most errors are cognitive and result from the application of one or more cognitive biases. Such biased reasoning is usually associated with 'System 1' (non-analytic, pattern recognition) thinking.

METHODS We review this literature and bring in evidence from two other fields: research on clinical reasoning, and research in psychology on 'dual-process' models of thinking. We then synthesise the evidence from these fields exploring possible causes of error and potential solutions.

RESULTS We identify that, in fact, there is very little evidence to associate diagnostic errors with System 1 (non-analytical) reasoning. By contrast, studies of dual processing show that experts are as likely to commit errors when they are attempting to be systematic and analytical. We then examine the effectiveness of various approaches to reducing errors. We point out that educational strategies aimed at explaining cognitive biases are unlikely to succeed because of limited transfer. Conversely, there is an accumulation of evidence that interventions directed at specifically encouraging both analytical and non-analytical reasoning have been shown to result in small, but consistent, improvements in accuracy.

CONCLUSIONS Diagnostic errors are not simply a consequence of cognitive biases or over-reliance on one kind of thinking. They result from multiple causes and are associated with both analytical and non-analytical reasoning. Limited evidence suggests that strategies directed at encouraging both kinds of reasoning will lead to limited gains in accuracy.

*Medical Education 2010: **44**: 94–100*
doi:10.1111/j.1365-2923.2009.03507.x

Department of Clinical Epidemiology and Biostatistics, McMaster University, Hamilton, Ontario, Canada

Correspondence: Geoffrey R Norman, MDCL 3519, McMaster University, 1200 Main Street West, Hamilton, Ontario L8N 3Z5, Canada. Tel: 00 1 905 525 9140 (ext 22119); Fax: 00 1 905 572 7099; E-mail: Norman@mcmaster.ca

INTRODUCTION

Medical errors represent an increasingly explored topic in the scientific and popular press. They are of many types and include medication errors, surgical mistakes or skill deficiencies, and misdiagnoses. Most of the research focuses on management error and current thinking is that most errors are a consequence of system failures resulting from poor communication between professional and patient or among health professionals, or poor back-up systems, and so on.[1] Not surprisingly, the solutions to such problems have been sought in systems design and the improvement of communications systems. The impressive reduction of errors in aviation has been used as a model and strategies borrowed from aviation, such as crew resource management, have been touted as potential solutions.

However, diagnostic error is different and should not be overlooked.[2–5] The root cause of diagnostic error is difficult to study as errors tend to be defined only in hindsight and the 'microscope' that can enable detection of mental processes in live time has yet to be invented. Still, the best work in the field suggests that, although errors occur in a minority of all cases, the majority of errors that do occur result, at least in part, from the individual doctor's cognitive processes.[2] Although diagnostic error does not necessarily lead to management error, both types of error need to be understood as both may affect patient outcomes. The intent of this paper is to review the state of the evidence as it pertains to diagnostic error in order to increase the community's potential to improve the diagnostic reasoning of both students and doctors.

THE PREVALENCE OF DIAGNOSTIC ERROR

As a starting point, we can ask how frequently diagnostic errors arise. Such a statistic is surprisingly elusive. Berner and Graber[6]conducted an extensive review of studies of diagnostic error of various types (e.g. autopsy studies, studies using standardised patients, and studies of specific conditions like myocardial infarction) in various settings and specialties. Their conclusion was that error rates in 'perceptual' specialties (e.g. radiology, pathology) are quite low, typically < 5%, but that error rates in other settings, such as the emergency room, are more likely to lie in the range of 10–15%.

THE PROXIMAL CAUSES OF DIAGNOSTIC ERROR

Perhaps the most informative study of diagnostic errors is that of Graber.[2] It is based on 100 cases of diagnostic error identified retrospectively from three academic medical centres over a 5-year period. Errors were classified as 'system-related' (technical failures or organisational problems), 'no-fault' (unusual presentation or patient-related such as deception or poor cooperation) and 'cognitive' (faulty knowledge, data gathering or synthesis). System-related errors were identified in 65 of the 100 cases, cognitive errors in 74 and no-fault errors in 44. On average, there were 5.9 cognitive or system-related errors per case; this latter figure highlights the challenge of studying this multifaceted and complex issue.

Graber examined cognitive errors most extensively, dividing them into four domains: Faulty Knowledge (11 occasions); Faulty Data Gathering (45); Faulty Information Processing (159), and Faulty Verification (106).[2] According to the author, the most common error was 'premature closure' ('the tendency to stop considering other possibilities after reaching a diagnosis'). However, although these categorisations are useful, they cannot reveal *why* there was a failure to order the right test, interpret the physical sign correctly or come up with the right diagnosis.

Although premature closure may be a result of sloppiness and of taking shortcuts, a more likely mechanism in most clinical situations is simply that the clinician did not think of the correct diagnosis and hence did not gather data relevant to it. Indeed, Graber presents evidence of this mechanism, finding that incomplete history taking or physical examination, failure to consider the correct diagnosis, and bias toward a single explanation are all correlated with premature closure.[2]

Of course, premature closure is not the only cause of diagnostic error that has been identified, but it provides a very interesting starting point in the discussion for reasons. Graber's study[2] is the only one we know of that has attempted to isolate diagnostic errors and identify the mechanisms by which they occur. In doing so, it exemplifies the problems encountered in trying to disentangle multiple causes, a necessary task if we are to contemplate appropriate remedial action. If the error is viewed as a consequence of premature closure – a processing bias – it follows that instruction which directs the doctor to be more thorough, to consider alternatives and to carefully interpret the data may suffice. However, diagnostic error may result from a failure to consider the correct diagnosis from the outset and this may, in turn, result from knowledge deficits rather than processing biases *per se*. The clinician may never have heard of 'myelodysplastic syndrome' or may never have seen a case. Less extremely, the clinician may never have seen a variant of the disorder presenting in the same way as the current case. When this is so, correcting the error is no easy matter because it relates to very specific knowledge gaps.

To further assist with disentangling the variety of mechanisms that might yield diagnostic errors, the rest of this paper will consider the issue from the perspective of three broad classes of outcomes common to the education literature: attitudes, skills and knowledge. Different authors have made claims that the root causes of diagnostic error lie in various of these areas. After reviewing these conjectures in turn, we will present a dual-process model of reasoning that might add to current understanding of how and when diagnostic errors arise and how they might be reduced.

ATTITUDE AND DIAGNOSTIC ERROR

Although this is overly simplistic, it is easy (perhaps especially for lay people) to default to thinking that errors represent a personal failing or lapse on the part of the clinician by making claims such as 'he was sloppy', 'he took shortcuts', 'she was inattentive or tired', 'she was distracted', and so forth. In short, diagnostic error is often discussed as resulting from poor attitudes towards best practice. Although Graber's study[2] identifies one or two examples in this category, these personal failings appear to arise infrequently. However, Berner and Graber,[6] in a comprehensive review article, make a more substantive case that diagnostic errors can result from the attitude of overconfidence. They cite several studies on doctor self-assessment and error recall, which show that, for example, 94% of academic doctors rate themselves as performing within the top half of their profession and that doctors have difficulty in recalling any errors they make.[7]

There is certainly good reason to presume a poor relationship between confidence and accuracy based on the extensive literature on self-assessment.[8] To our knowledge, however, there has been no attempt to improve diagnostic accuracy by an attitudinal intervention although many have expressed concern about the need to nurture self-aware professionals. Such an initiative may represent a double-edged sword: an intervention targeted at reducing overconfidence without improving accuracy might succeed only in increasing costs of laboratory investigations as clinicians buttress their newfound lack of confidence with a quest for additional information, thus increasing the rate at which skill (or processing) difficulties lead to mistakes.

COGNITIVE SKILLS AND DIAGNOSTIC ERROR

Graber's study[2] leads to the conclusion that cognitive skill errors (processing biases) are far more common than errors caused by knowledge gaps. This is consistent with the predominant literature on diagnostic errors, in which many papers have been published, dating back over two decades, indicating, by exhortation or example, how clinicians might fall prey to these biases.[5,9–14]

To give the reader some sense of the variety of these biases, we provide a few of the more common examples. As these have been extensively described elsewhere,[12] our descriptions are deliberately brief.

- Availability: tendency to judge diagnoses as more likely if they are more easily retrievable from memory.
- Base rate neglect: tendency to ignore the true rate of disease and pursue rare but more exotic diagnoses.
- Representativeness: tendency to be guided by prototypical features of disease and miss atypical variants.
- Confirmation bias: tendency to seek data to confirm, not refute, the hypothesis.
- Premature closure: tendency to stop too soon and not order the critical test or gather the critical information.

The identification of each bias has its roots in the research programme conducted by Kahnemann and Tversky[15,16] during the 1970s; claims of the impact of each bias are based largely on a number of individual studies, typically using everyday decisions and ubiquitous cohorts of undergraduate psychology students as participants. In actual clinical situations it is extremely difficult to retrospectively identify the cause of a diagnostic error, as discussed in the context of the Graber study[2]. Indeed, as Wears and Nemath[17] argue, attempts to retrospectively deduce what went wrong may themselves fall prey to a well-recognised 'hindsight bias', in which 'those who know what happened after the fact consistently overestimate what others who lacked the knowledge could have known … reviewers who know the outcome of a case glibly judge cues to the correct diagnosis as being much more evident than they actually were…'

More fundamentally, it is important to note that, although the diagnostic error literature highlights the tendency of individuals to be influenced by cognitive heuristics and biases and the error proneness this tendency creates, there is ample reason to believe that attempts to overcome these cognitive strategies can themselves cause error.[18,19]

Although Graber's study[2] concludes that the dominant type of error involves premature closure, which might be prevented by gathering additional data, there may also be danger in the pursuit of additional information. Redelmeier *et al.*[20] show that, when health professionals actively seek information (rather than being provided with the same information from the outset), they perceive the data they acquire as more salient and have greater confidence in their subsequent decisions, although the information they are using is identical.

To illustrate further how some of these biases can play out in clinical contexts, let us take a deliberate caricature of a resident who diagnoses migraine in a patient with headache which turns out to be caused by a tumour. The resident might be accused of falling prey to the bias of availability because he may have seen another patient with a migraine recently, or to that of representativeness because the patient may show some features consistent with a classic migraine presentation. The resident might be accused of confirmation bias because he may have sought information consistent with migraine and not pursued data consistent with other diagnoses. He may be accused of premature closure, because he did not order a computed tomography (CT) scan to rule a tumour in or out. However, if the patient actually has a migraine these same psychological processes will lead to the correct diagnosis and whether or not the resident was influenced by cognitive bias will not come into consideration.

These examples highlight two serious problems with the notion of cognitive bias. Firstly, thinking about cognitive bias solely as a source of error is inconsistent with the psychological literature on the subject.[18] In psychology, heuristics and biases are viewed as efficient mental strategies with which to deal with an uncertain and ambiguous world. On many occasions they work; occasionally they fail. But they are not intrinsically bad.

Secondly, although many (but not all) of these biases have been established experimentally, this occurred in situations in which variables could be manipulated singly and clever manipulations were designed to induce error for the sake of determining if the biases exist. Even experimentally it is hard to observe 'biases' in situations where the biases lead to the correct answer. By contrast, when trying to conduct a retrospective examination of a diagnostic error, there is no way to deduce the presence or absence of any error as errors are overlapping and there is no process trace to indicate when and if a particular error arose in the diagnostician's mind.

KNOWLEDGE AND DIAGNOSTIC ERROR

As we indicated, Graber found that a minority of errors were caused by knowledge deficits (11/345, 3.4%).[2] However, here too there is a potential misattribution. Far and away, the leading cognitive bias in the study is premature closure, but, as we have shown, premature closure may well indicate that the doctor simply did not think of the correct diagnosis and so failed to identify or elicit relevant data. Is this a process (reasoning) error or a knowledge deficit?

We do know that measures of formal knowledge decline with age.[21] In addition, work by Norcini *et al.*[22] and Tamblyn *et al.*[23] shows a relationship between performance on knowledge-based licensing or certification examinations and competence in practice. Therefore, positing a relationship between knowledge and diagnostic accuracy is not at all far-fetched, although direct evidence is sparse.

CLINICAL REASONING, DUAL PROCESSING, COGNITIVE BIASES AND DIAGNOSTIC ERROR

We previously published a pair of papers reviewing current evidence on the nature of clinical reasoning.[24,25] In brief, we reviewed evidence that clinical reasoning consists of two distinct (although not exclusive) classes of mental processes that have been labelled 'analytical' (AN) and 'non-analytical' (NA).

This 'dual-processing' account of thinking has been extensively explored in psychology[26,27] and the two classes of reasoning strategies shown to be anatomically and physiologically distinct.[27] Non-analytical processing proceeds by an unconscious holistic match to a prior example stored in memory,[28] so is rapid, unconscious and contextualised, whereas AN reasoning is slow, deliberative, logical and conceptual, amounting to the logical application of the 'rules' of diagnosis.

One attractive feature of this dual-processing account of reasoning is that it provides an explanation for the presence of some of the cognitive biases alluded to earlier. For example, as NA reasoning amounts to the retrieval of specific instances (exemplars) from memory, it will inevitably be influenced by the representativeness of the new problem and the availability of prior similar cases.

Indeed, some writers place the blame for errors squarely on the shoulders of NA reasoning (called 'System 1' thinking). Representative statements include:

'System 2 [analytic] … can be seen as the superego of decision making, fighting off the primary impulsivity of System 1 [non-analytic] in favour of reality testing, analytic judgement, metacognition and affect tolerance. It is the ''conscience'' of decision making…'[29]

'Cognitive forcing strategies … are designed to prevent clinicians from pursuing a pattern-recognition path that will typically lead to error.'[14]

Paradoxically, others in the psychology literature provide evidence for precisely the opposite conclusion, based on a number of studies showing that inducements to conscious reasoning result in poorer performance.[30] Why? Because analytical reasoning, unlike System 1 thinking, places a heavy load on working memory, which has real limitations in speed and size.[27] Rather than a speed–accuracy trade-off, given the limitations of memory, we might actually consider a slowness–accuracy trade-off. Further, although several authors caution against encouraging novices to rely on System 1 processing,[31] one study[32] shows that novices approaching everyday problems are better off when encouraged to use a holistic intuitive approach and experts do better when encouraged to use an analytical strategy.

In any case, there is no basis for associating bias solely with one process or another. Some biases – availability and representativeness – may well be primarily related to the process of hypothesis generation, which is more non-analytic. By contrast, data gathering is a highly directed activity, but has been shown to be strongly influenced by search for confirmatory information.[33]

In conclusion, ascribing diagnostic errors to one kind of process or another is unlikely to be profitable for a number of reasons. Firstly, instances in which the clinician relies solely on one process are probably rare. Secondly, errors are likely to result from an interaction between knowledge deficits and processing problems, not from one or the other alone, and, thirdly, emphasising only one type of process may reduce the rate of errors of some types, but only at the expense of increasing the rate of errors of other types.

WHAT CAN WE DO ABOUT IT?

The notion that diagnostic errors are caused by cognitive biases is now so entrenched that resources are expended to educate these biases out of clinicians and medical students. Perhaps the most visible champion of debiasing strategies is Croskerry,[10] who has written extensively about cognitive bias ('cognitive dispositions to respond') and 'cognitive forcing' or 'metacognitive' strategies to reduce their impact. However, he is not alone; Redelmeier[11] and Mamede *et al.*[14] also propose potential error-reducing strategies. Common to both Redelmeier[11] and Croskerry[10] is the assumption that informing students about the existence of these biases, and achieving understanding of what they are, will be sufficient to reduce error. As Redelmeier *et al.* say, in an introduction to a series:

'Awareness of this science [cognitive psychology] might accomplish three things. First it might broaden the list of pitfalls that a clinician can anticipate and possibly avoid. Second, it can provide a language and a logic for understanding repeated mistakes. Third, it may encourage greater circumspection…'[34]

Although there has been much discussion about implementing cognitive debiasing or forcing strategies, these have not been accompanied by investigations of effectiveness.[35] Teaching cognitive biases and debiasing strategies in a didactic approach, with the assumption that these are general strategies that can be applied routinely, requires two strong assumptions about the nature of cognitive biases, both of which are inconsistent with principles of cognitive psychology. Firstly, it is assumed that the biases are consciously applied and thus an awareness of their application will be sufficient to counter them. One can imagine our hypothetical clinician saying something like, 'Oh, I'm thinking of migraine. That might be an issue of availability. I had better check on this and think of more obscure possibilities.' Such error-checking strategies are described in various terms – metacognition, reflection, debiasing, cognitive forcing – but share the common characteristic of conscious and deliberative thinking. Although it is clearly too strong to argue that introspection cannot and does not occur, as Bargh[36] shows, we do indulge in many cognitive activities and biases without any conscious awareness. Wears and Nemath[17] state: 'For experts in a field of practice, this problem framing occurs mostly unbidden and without effort.' They go on to describe attempts to debias the reviewers of diagnostic errors (not the clinicians themselves): 'Hindsight and outcome biases are also preconscious and cannot be overcome by simply willing ourselves to ignore them anymore than we can will ourselves to be taller. Cautioning reviewers not to let outcome knowledge influence their judgement is equally ineffective.'[17]

The second issue is that cognitive bias is treated as a general phenomenon that one can develop generic skills to avoid. It is assumed that the bias will play out in all domains equally and that teaching about bias in one domain will ensure its usefulness in all domains. This flies in the face of our knowledge of transfer – applying concepts from one domain to another – which turns out to be extremely limited.[37] There is every reason to suppose that, if representativeness bias is learned around a headache problem, it may well be recalled and used to solve a second headache problem, but is much less likely to be activated for a diabetes problem. There is little discussion about the interaction between knowledge and skill. If the clinician has not heard of amyotrophic lateral sclerosis (ALS), no amount of introspection about cognitive bias will make him think of it when faced with a patient with progressive paralysis. Conversely, recent experience with ALS may induce an opposite bias. As an example, Hashem *et al.*[38] show that subspecialists tend to overdiagnose into the particular organ system in which they specialise.

However, there has been some success with interventions that encourage dual processing implemented at the time of problem solving. Eva *et al.*[39] systematically demonstrate that interventions aimed at encouraging absolute novices to use both kinds of process during electrocardiography diagnosis show small but consistent effects. Along a similar line, Mamede *et al.*[14] show that encouraging NA reasoning leads to small gains with simple problems and encouraging AN reasoning leads to improvements with difficult problems, underlining the interaction between process and content. Further work is needed to determine the extent to which these types of strategies generalise across contexts, but the early results yield promise.

These small, but successful, attempts may support the development of strategies for future interventions. They were designed to be implemented by the clinician during the course of reasoning, as opposed to retrospectively after the process is complete. Further, they were designed within a theoretical framework of a dual-processing model of reasoning, so that explicit instructions encourage reasoners to use both strategies. Finally, they were developed with strong emphasis on the application of simple and transparent strategies, and the interaction with specific knowledge in memory – 'Think of the first thing that comes to mind', 'Think of other possibilities' – and not on the didactic presentation of a series of cognitive biases in which the instructional goal can easily be misinterpreted as one of remembering definitions.

Contributors: GRN contributed to the conceptualisation of this paper and produced the manuscript. KWE contributed to the conceptualisation of the paper and reviewed and commented on the manuscript. Both authors approved the final manuscript for publication.
Acknowledgements: none.
Funding: this research was supported by the Natural Sciences and Engineering Research Council, Ottawa, Ontario, Canada, and the Social Sciences and Humanities Research Council, Ottawa, Ontario, Canada.
Conflicts of interest: none.
Ethical approval: not applicable.

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Received 17 February 2009; editorial comments to authors 7 April 2009, 12 June 2009; accepted for publication 21 July 2009