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Teaching and learning clinical decision-making for person-centered medicine: recommendations from a systematic review of the literature

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Abstract

Rationale, aims and objectives: Clinical decision-making (CDM) has been studied from diverse perspectives, including diagnostic cognition, clinical error and probabilistic modelling of patient management under uncertainty. This paper aims to establish the current knowledge base for CDM by systematic review, in order to produce recommendations for clinicians and clinical teachers.

Method: Biomedical, social science and education databases were searched. All English-language articles concerning CDM in medical education, from peer-reviewed academic journals, were included. Meeting abstracts were hand searched for relevance. Two hundred and thirty-six citation abstracts were kept for consideration, then themed for ease of analysis. Current thinking was reviewed and discussed and key recommendations for teaching CDM were made for clinicians.

Results: The hypothetico-deductive cognitive method is criticised, as experts use little hypothesis testing. Clinical expertise is associated with better content-specific memory, consisting of encapsulated biomedical and clinical knowledge as goal-directed knowledge-structures (illness scripts). These are rich, accessible and activated intuitively (pattern recognition). Decision theory and Bayes' theorem provide a mathematical rule for rationalising a hypothesis and enable decision analysis for complex decisions. Clinicians should appreciate the nature and impact of cognitive errors on CDM and use cognitive forcing strategies to lessen them.

Conclusion: Analytical and non-analytical (intuitive) models of CDM are not mutually exclusive and dual-process or additive models of CDM account for this. Key recommendations for clinical teaching include development of knowledge encapsulations as individual constructs, combined learning of analytical and intuitive elements and reducing cognitive error by metacognition, forcing strategies and constructive feedback.

Keywords

Clinical decision-making, clinical education, clinical reasoning, cognitive error, decision theory, medical education, person-centered medicine, problem-solving, systematic review

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Introduction

For clinicians, making a decision about patient diagnosis or management in the face of uncertainty is a frequently occurring problem. How such decisions are made can be examined in order to enable junior colleagues and medical students to learn similar skills. As such, it is necessary to understand the difference between a novice and an expert decision-maker and how or at what stage in training, should complex decisions or decision-making under uncertainty, be learned. The 2008 Modernising Medical Careers Inquiry called upon the medical profession to speak coherently and define its unique role amongst health professionals [1]. Indeed, doctors "regularly take ultimate responsibility for difficult decisions in situations of clinical complexity and uncertainty… drawing on their knowledge and scientific judgment" [2]. In addition, doctors must be capable of assessing and managing risk and have the ability to work outside protocols when circumstances demand [3]. The General Medical Council agrees that medical students, too, should become critical thinkers and good decision-makers [4].

The terms clinical decision-making (CDM), problem-solving, diagnostic reasoning and clinical reasoning have been used interchangeably. They refer to the idea that certain cognitive processes are required to evaluate and manage a patient's medical problem [5]. Norman describes the literature on CDM as "as diverse as the perspectives of the researchers themselves" [6]. Indeed, the theory of CDM has been studied from perspectives such as philosophy, cognitive and clinical psychology, clinical education and sociology, making it challenging to access and then integrate because of the heterogeneity not only of the terms used, but also of research methods. Cognitive research has been directed at describing the diagnostic process (based on history and examination), most often using clinical reasoning as a moniker. However, normative decision theory and analysis have been influenced by mathematical models of management under uncertainty and are therefore concerned "with what doctors should do, rather than at what they do do" [6]. Although CDM has been the subject of selective narrative reviews [5,7] and chronological perspective articles on diagnostic reasoning theories [6,8], there has been no synthesis from all quarters and little practical recommendation for clinicians on the "shop-floor" based on the best available evidence. The aim of this paper is to establish, *via* systematic review, the current knowledge base for CDM, in order to produce key recommendations with practical guidance for clinician teachers in a clinic, surgery or on the ward.

Method

A systematic database search was undertaken, using established guidance for searching in medical education [9]. The following biomedical, social science and education databases were searched: MEDLINE (1950-December 31st 2011), EMBASE (1950 – December 31st 2011), Education Resources Information Centre (ERIC; 1966-December 31st 2011) and PsycINFO (1806-2011). Keywords used were: (Clinical decision making OR decision making OR clinical judgment OR clinical reasoning) AND (medical education OR education OR clinical education). CinAHL (1980-2011), Education Research Complete (ERC), British Education Index (BEI) and System for Information on Grey Literature in Europe (SIGLE) Archive were searched using the keywords: Clinical reasoning OR Clinical decision-making. The Cochrane Library and Best Evidence Medical Education (BEME) archive were searched using the keywords: Clinical reasoning OR Clinical decision-making OR Medical education. Conference abstract books (2006-2010) of the Association for the Study of Medical Education (ASME) and Association for Medical Education in Europe (AMEE) were hand-searched. Articles published in peer-reviewed academic journals in the English language were included. Duplicate, foreign-language and non-peer-reviewed articles were excluded, as well as articles relating to professions other than medicine. Two hundred and thirt-six citations were selected and their abstracts hand-searched for relevance, then themed for ease of analysis (for example: normative theories, descriptive theories, cognitive error). Key recommendations for clinician teachers were formed based on a critical review of the literature.

Results

1. Descriptive theories

Information processing theory

From the earliest studies on CDM, a general theory called the hypothetico-deductive method emerged [10-12]; solutions to diagnostic problems were identified by making a small number of hypotheses early in the process and using backward reasoning to collect data that helped confirm or, less often, refute each hypothesis. Experts were distinguished from novices by better-formed hypotheses [7]. Diagnostic errors were thought to be due to either a failure to consider enough hypotheses [5], poor data collection strategy or misinterpretation of results [7]. However, it was criticised as a general theory: success on one problem was a poor predictor of success on another [6], a feature that Elstein called 'content specificity' [10,13]. Expertise in problem solving differed between clinicians and was dependent on the degree of knowledge acquisition in a domain [14]. Furthermore, expert reasoning in familiar situations frequently did not involve any hypothesis testing at all [7], suggesting that experts used a different reasoning method to novices, at least when encountering familiar situations.

In modelling expert behaviour, Dreyfus and Dreyfus stated that artificial, analytical-type intelligence would always be inferior to human intuition [15]. Benner [16] adapted the Dreyfus model to nursing, suggesting that a learner passed through 5 stages of proficiency from novice to expert; movement through each stage was characterized by a change from reliance on following abstract principles to familiarity with patterns and demand situations; analytical strategies were abandoned in favour of an unconscious knowledge of the required action, known as intuition. A subsequent criticism has been that empirical evidence for intuition was lacking and therefore the "expert" stage lacked clarity [17].

Memory and expertise

One fundamental empirical finding on expert-novice comparisons was enhanced recall: experts had superior memory skills in their domain [18]. In the original study, when presented with midgame playing positions, expert chess players could recall them near-perfectly and novices performed poorly. However, the position of the pieces had to derive from legal chess moves and random positioning resulted in experts' performance equalling that of novices. Thus, expertise was not due to general memory ability, but memory was enhanced by experts' ability to perceive meaningful patterns [19]. However, in medicine, Coughlin and Patel found that there were no significant differences in recall between family physicians and second year medical students, but physicians tended to remember more critical information and less non-critical information [20]. Schmidt and Boshuizen showed that when there was no time constraint, intermediates, that is, senior medical students recalled more than experts [21]. However, when results were corrected for time of exposure, there was correlation of recall with expertise. Schmidt and Boshuizen proposed "encapsulation" or grouping of multiple factors under one label leading to enhanced recall of critical information [19].

Role of biomedical knowledge

Feltovich and Barrows hypothesized that clinical diagnosis emanated from mere comprehension of relevant biomedical knowledge [22]. Boshuizen and Schmidt challenged this position and suggested that as a result of repeated patient encounters, experts' biomedical knowledge was encapsulated into clinical knowledge [23]. In their experiments using think-aloud protocols, they showed that the application of biomedical knowledge was a characteristic of novice reasoning and experts used little biomedical knowledge in day-to-day CDM. Critical of the comprehension model, but in contrast to knowledge encapsulation, Patel *et al*. described biomedical knowledge and clinical knowledge as unique domains ('2 worlds') with separate mental representations and, for day-to-day decisions, experts used very little biomedical knowledge [24]. So why learn biomedical science at all? Patel *et al*. suggested that causal mechanisms provided explanations for communicating clinical phenomena and could aid transition [24].

In difficult, novel or uncertain situations, experts' use of biomedical knowledge increased [25], sometimes by postulating disease mechanisms to reason a diagnosis [26,27]. The learning of causal mechanisms improved novices' diagnostic skills immediately and, after a delay, when compared to rote learning of clinical features [28] or probabilistic data [29]. Woods *et al.* concluded that the value of basic science was in creating mental representations that helped reconstruct features of a disease or diagnostic category and coherent encapsulated knowledge [29,30].

Script theory and illness scripts

Scripts are knowledge structures that are organised in response to repeated real-world experiences [31]. It is assumed that individuals have hundreds of them and combinations are invoked in any complex situation. Once verified by an episode of correct activation, the scripts become instantiated as context-specific exemplars. Schmidt and Rikers proposed that illness scripts contained a wealth of encapsulated clinical knowledge concerning "enabling conditions" of a disease, which increased accuracy and speed of diagnosis [32]. An example of an enabling condition which allows the expert decision-maker to rule in or out a number of diseases causing fever, would be 'travel to Africa' or 'current influenza pandemic'. Several authors showed that under richer enabling-conditions, knowledge developed with increasing expertise [33,34] and experts' diagnostic skill was no better than novices in scenarios where enabling-conditions were removed [32]. Bordage *et al*. described bipolar enabling conditions called semantic qualifiers (SQs), often symptoms and signs (e.g., large joint *versus* small joint), which in experts were shown to be rapidly organised and utilised to provide accurate diagnoses [35]. However, Nendaz and Bordage showed that when students increased the number of SQs used, the diagnostic accuracy did not increase, leading them to suspect that conceptual abstraction may not be sufficient to ensure accuracy [36]. Indeed, Auclair observed that diagnostic accuracy was related to an understanding of relationships between concepts [37].

Each diagnostic hypothesis represented an activated illness script; thus, if only one script appeared, then this was the most likely diagnostic line. If more than one script appeared for a particular presentation, as clinical features can belong to more than one script, deeper reasoning was required to make the correct diagnosis [31,38]. Scripts only became context-specific once instantiated. For most doctors, it was proposed that scripts formulated as medical students formed the basis for clinical enquiry and management lines in clinical practice [31]. The process of incorporating new knowledge into existing illness scripts has not been studied, but illness scripts would require modification as a result of changes in disease prevalence, changing geographical area of clinician's practice or changes in management strategy. Schmidt and Rikers have suggested that biomedical science should only be taught to the extent that is relevant to encapsulation concepts [32]. The encapsulation process should be supported by integrated teaching; that is, through an organ system-based curriculum, rather than a 2-phase pre-clinical/clinical system and students should be allowed to work with varied patient problems early in the curriculum, allowing better encapsulation and accurate illness script formation [39].

Thus, the organisation of knowledge is as important as the content of biomedical and clinical knowledge in clinical teaching [40]. Early exposure to authentic professional tasks starts the acquisition of diagnosis scripts early, as long as care is taken with integration of well-structured knowledge bases. The acquisition of accurate diagnosis scripts cannot be left to variation of clinical exposure later in the course.

Non-analytical reasoning: pattern recognition

The role of experiential knowledge in CDM has been examined and highlights a theoretical bipolar division between analytical theories and the role of non-analytical reasoning. Norman states that "the many categories that we use in our representation of the world are defined, in part, by a large collection of examples derived from past experience and when we must classify an object we do it by rapid retrieval of a similar prior example, without conscious awareness" [6]. The fact that experts' decision-making in familiar situations does not involve hypothetico-deduction or recall of biomedical knowledge [7], suggests intuitive categorization (pattern recognition). Indeed, the activation of scripts is thought to be intuitive and based on past experience, rather than on conscious analysis [6].

Category assignment can be based on specific instances (exemplar theory) or by a more abstract prototype model [7, 41]. More accurate and rapid diagnosis has been demonstrated in dermatologists with prior exposure of skin conditions [41] and cardiologists with prior exposure of electrocardiographs [42] when compared with novices who followed analytical interpretation rules. Coderre *et al*. had concluded that pattern recognition was dangerous in the hands of novices, though no deleterious outcomes have subsequently been demonstrated [43]. There is no research illustrating that the nature of pattern recognition in novices and experts differs, although it is intuitive to think that experts will have a richer, more varied and possibly more quickly accessible bank of exemplars within a particular domain.

Young *et al*. showed that, for novices at least, familiar symptom descriptions (such as "patient is sleeping more", rather than hyper-somnolence) improved diagnostic accuracy over novel but standard symptoms labels [44]. Therefore, the impact of familiarity has a bearing on the novice at the stage of basic translation into medical language. This has implications for teaching, showing that "from the moment a patient walks through a clinic door... she is communicating with the doctor.... her gait, colouration, mannerisms and appearance all provide information that may influence a diagnosis in ways not captured by a strictly analytic understanding of the process of diagnosis" [44].

2. Normative theories

Decision theory

Decision theory is an expected utility theory, which suggests that humans will try to maximise the value of their decision [5]. It addresses the problem of scientific induction; that is, the challenge of determining the validity of judgments about the future or under uncertainty [45]. Thus, from the point of view of decision theory, making a diagnosis means updating one's opinion with imperfect clinical evidence [7]. Evidence-based medicine is the most recent and arguably most successful clinical application of decision theory [46]. Clinicians who have been trained in evidence-based medicine are more likely to use a Bayesian approach to CDM [7,47]. Bayesian analysis attempts to treat the probability of a theory as a product of the degree of one's belief in it. Therefore, with respect to clinical diagnosis, Bayes' theorem provides a mathematical rule for updating a hypothesis when new information is received. Knowledge (e.g., the presence of a disease) is represented by a probability, which is an abbreviation of the subjective likelihood of its occurrence. The value of a diagnostic test (the likelihood ratio) is the chance of having a positive test when the disease is present, divided by the chance of having a positive test when the disease is absent [5]. The pre-test probability is modified by the likelihood ratio of the diagnostic test to produce a post-test probability of occurrence as follows:

Post-test probability of occurrence = Pre-test probability of occurrence x Likelihood ratio

However, many medical decisions are complex and multiple; thus, decision analysis is an extension of decision theory in which a complex decision is broken down into a number of single decisions. Humans cannot handle the simultaneous analysis of many numerical values as a computer might [5]. The complex decision is represented by a *decision tree*, on which branches provide a visual representation of value probabilities. Doubilet and McNeil have successfully used decision analysis for CDM in the treatment of gastric carcinoma [48] and McNeil and Adelstein have used it to illustrate the value of diagnostic tests [49]. Round undertook a controlled trial of fourth year medical students where the intervention group received teaching on a diagnostic case, used to explicitly teach about bias, Bayes' theorem and decision analysis. They scored significantly better on a validated assessment tool [50]. Elieson and Papa have shown that students make better clinical diagnoses when provided with probabilistic information about frequency of symptoms, than with narrative information or with 'soft' descriptors of likelihood, such as 'usually', 'rarely' or 'frequently' [51]. Computerised decision support tools have been evaluated in practice. The Quick Medical Reference (QMR) program [52] and Isabel [53] increase diagnostic accuracy, reduce diagnostic error and have the potential to remind trainees about red-flag diagnoses at the consultation. They have not proliferated in acute settings and have been criticised for lengthy consultation times and imprecision associated with being applied to complexities when intended only for simple problems [53,54]. It should be said that medical students already access prevalent electronic resources extensively, such as the Internet search engine Google or Isabel, for dealing with complex diagnostic decisions [55] without necessarily having formal faculty instruction.

A major criticism of decision theory is the assumption that psychological processing of probabilities does not deviate from the ordinary probability scale; however, even expert clinicians deviate from analytical opinion revision in daily practice, regularly using non-analytical methods [7]. For example, prospect theory [56] proposes that in CDM, small probabilities are overestimated and large probabilities are underestimated. As Elstein and Schwartz suggest, "this compression of the probability scale explains why the difference between 99% and 100% is psychologically greater than the difference between 60% and 61%" [7]. Additionally, many people weigh losses more heavily than gains and are risk averse, preferring the certainty of a moderate outcome to 'gambling' for a smaller chance of a superior outcome [5]. Regret theory suggests that decision-makers consider all outcomes and the regret they would feel if they failed to pick the correct outcome. If the regret is large, this outweighs interpretation of linear probabilities [57]. Indeed, there is a tendency to overestimate the likelihood of serious diseases, because the risk of missing something serious is perceived as far greater.

Table 1 Cognitive dispositions to respond (CDRs) that may lead to diagnostic and management error [59,61,62,72,89]

Step	Bias	Definition	Example
Generating a differential diagnosis	Availability or Recall bias	Diagnosis influenced by what is easily recalled, creating a false sense of prevalence	Clinician sees a 40-year old woman with hip pain diagnosed as lymphoma. Clinician subsequently evaluates all patients with hip pain for lymphoma
Generating a differential diagnosis	Ascertainment bias – including gender and stereotyping	When a clinician's thinking is shaped by prior expectation	Not willing to consider a new diagnosis of HIV-related illness because the patient is heterosexual with a family
Validating a diagnosis	Confirmation bias	Additional tests make suspected diagnosis more likely, but fail to test competing hypotheses	A 55-year old man with chest pain suspected to be angina has a 12-lead ECG with non-specific abnormlaities. However a chest X-ray is not performed to look for a pneumothorax and the 12-lead ECG does not help confirm this
Selecting a diagnosis from a differential	Anchoring or Adjustment bias	Tendency to fixate on first-impression hypothesis and failure to take into account new information	Patient admitted with viral respiratory tract infection has a headache and fever, which is on-going and worsens, but is attributed to systemic viral infection. In fact, patient has developed a brain abscess
Selecting a diagnosis from a differential	Premature closure or bounded rationality	Acceptance of diagnosis before it has been fully verified and clinician stops searching for additional diagnoses	An elderly lady falls out of bed and complains of hip pain. A hip fracture is diagnosed, but the hyponatraemia precipitating the fall is missed
Patient treatment	Outcome bias	Tendency to opt for treatments with previous positive outcomes, rather than the evidence supporting the treatment at the time of diagnosis	A 62-year old woman with asthma is given a theophylline tablet with no good evidence base for its use, because positive outcomes have been achieved with 2 previous patients
Patient treatment	Extrapolation bias	Tendency to generalise treatment to groups of patients in whom the therapy has not been evaluated	A 78-year old man with chronic heart failure and a low ventricular ejection fraction is given an ACE-inhibitor to improve function, but develops hyperkalaemia and acute-on-chronic kidney disease. The ACE-inhibitor was validated for heart failure but only patients without chronic kidney disease

3. Cognitive error

Studies in patient safety and adverse events give an idea of the prevalence of error in clinical practice. Five to 14% of clinical diagnoses in acute hospital admissions are incorrect or missed [58,59] and Shojania *et al*. revealed diagnostic error rates of up to 25% at autopsy [60]. It is difficult to discriminate between pure cognitive error and the contribution of environmental determinants, such as time pressure and resource allocation [59]. Recent studies showed that although a third of adverse events were due to errors of execution (slips and lapses), up to a half involved clinical decision-making errors [59], including failure to elicit or synthesize clinical features, or make a decision.

Heuristics are mental shortcuts or rules-of-thumb, which are accurate in many situations, but can predispose to error if relied upon at all times [59]. Pertinent examples would be Occam's razor – looking for a single diagnosis that explains all of a patient's clinical findings or Sutton's Law – favouring common diagnoses over uncommon ones [61]. Indeed, much CDM is done when there are time and resource constraints and so shortcuts can be advantageous [62]. *Biases* are inaccurate beliefs that affect CDM [63]. Scott categorizes bias into internal values bias (clinicians' values, pre-conceived beliefs and emotions), agency bias (clinicians put their own interests ahead of the patient), expectation bias (what the clinician expects from a doctor-patient relationship) and externality bias (due to time and resource constraints) [59]. Croskerry provided an extensive and complex list of cognitive biases called *cognitive dispositions to respond* (CDRs), where the term CDR was posed to remove stigma associated with bias [64] (Table 1).

Groves *et al*. examined the relative contributions of inadequate knowledge, poor data interpretation and poor hypothesis generation to diagnostic errors, in medical students (novices) and general practitioners (experts) [65]. Unsurprisingly, hypothesis errors decreased as expertise increased, but there was a paradoxical increase in knowledge and interpretation errors. They postulated that inappropriate pattern recognition and failure of knowledge base with expertise was responsible. Furthermore, although hypothesis errors increased with problem complexity, knowledge and interpretation errors actually decreased. At high levels of complexity, clinicians at all levels of expertise may well be less able to differentiate between relevant and irrelevant clinical information, so give equal weighting to all aspects, or patterns. Preliminary data have shown that querying an initial diagnostic hypothesis does not harm a correct diagnosis, but instead allows medical students to rectify any incorrect diagnosis, though the

Table 2 Biases that lead to overconfidence in CDM and strategies to overcome them [69,70,89]

Bias	Definition	Correction Strategy
Denial of Uncertainty	Barrier against the belief that certainty is not always possible	Encourage the use of ‘not yet diagnosed’ or ‘syndrome yet for diagnosis’ tags, to overcome personal and cultural barriers against admission of uncertainty
Confirmation bias (biased evidence gathering)	Having strong support or evidence for ones’ viewpoint, means opposing evidence is not considered	By forcing a consideration of alternative diagnoses, using a *consider-the-opposite* strategy. Judgements are better calibrated when there is an obligation to consider disconfirming evidence [89]
Base-rate neglect	Not appreciating the incidence and prevalence (likelihood of occurrence) of a particular diagnosis, in a certain region or population	Supply current incidence and prevalence data for common diseases, for particular groups in geographical areas
Low level of critical thinking	Simple conclusions made without consideration of complexity and rationality of a particular problem	Addressing different levels of complexity when learning clinical decision-making skills. An appreciation of traditional basis for rational thought

effect on diagnostic error in clinical practice remains unknown [66].

Historically, physicians have tended to overestimate their diagnostic ability, placing credence in incorrect diagnoses in 10-15% of cases [67]; for instance, chest physicians are demonstrated as highly susceptible to omission and *status quo* bias [68]. Indeed, overconfidence is seen as a barrier to good CDM [69] and deserves closer scrutiny. The cognitive evolutionary perspective sees overconfidence as a general feature of human behaviour, where equivocation is considered a sign of weakness and vulnerability. Overconfidence also correlates with level of task ease, the amount and strength of supporting evidence people can find for their standpoints, lack of critical feedback and dominance of personality [70]. Also, intuitive CDM is associated with strong emotions such as excitement and enthusiasm [71], so it follows that individuals would be accepting of decisions they have come to without looking for disconfirming evidence. Croskerry and Norman suggested that good CDM is enabled by the ability to modulate intuitive with analytical thinking and *vice versa*; thus tempering bias [70]. Sources of bias from overconfidence are shown, with correction strategies, in Table 2.

Cognitive pills for cognitive ills

Often, clinicians do not change an incorrect diagnosis, even if the correct one is suggested by peers or by a decision support tool [59]. Reducing error in CDM is dependent upon clinicians’ ability to monitor their own cognitive processes. *Metacognition* describes an individual’s ability to stand back from their thinking, to observe it and recognize opportunities for interventional strategies [72]. It requires awareness of the requirements of the learning process, recognition of the limitations of memory, the ability to appreciate perspective on a problem, capacity for self-critique to avoid overconfidence and the ability to select different and novel strategies. Indeed critical reflection on thought, emotion and behaviour is central to experiential learning [73,74]. In contrast to heuristics, cognitive forcing strategies are de-biasing techniques that introduce self-monitoring of CDM; this depends upon the clinician consciously applying a metacognitive step and forcing an alternative strategy. Croskerry suggests a 3-level model for learning cognitive forcing strategies in Emergency Medicine: level 1: basic knowledge of the theory of error, level 2: an understanding of common biases in clinical practice and level 3: specific scenarios in which biases occur (pitfalls) and avoidance strategies [72]. A working knowledge of cognitive error theory has a number of advantages from the outset: as well as being a metacognitive component from which level 2 and 3 requirements intuitively follow, a lexicon of error allows more effective communication within departments and diligence in practice is forced, because clinicians are aware that pitfalls that may occur. Educators need to be aware of common pitfalls in their clinical areas when constructing curricula for learning CDM and blueprinting general and specific requirements may be helpful; level 1 and 2 requirements are transferable to other clinical areas. In addition to cognitive forcing, a number of other strategies to reduce error have been described: use of simulation, rapid feedback, encouraging accountability for decisions, minimizing time pressure and use of cognitive aids such as mnemonics and algorithms [59,62]. Although de-biasing strategies have face validity and have been evaluated in simulation scenarios, they have not been formally evaluated in preventing error in clinical practice. In addition, there are possible unintended consequences in terms of decisional delays (‘paralysis by analysis’), unnecessary and protracted investigation and patient anxiety as a response to expressions of uncertainty [59,75].

4. A systematic approach to CDM

There has been increasing recognition that the analytical/non-analytical (intuition) models of CDM are not binary or mutually exclusive. Indeed, cognitive continuum theory [76] suggested that analysis and intuition were “combined and combinable” - certain tasks required more or less of an analytical or intuitive approach [77,78]. For instance, for a given patient, the major uncertainty for

Table 3 A comparison of System 1 and System 2 processes in CDM [54]

	System 1 (Intuitive) processes	**System 2 (Analytical) processes**
Examples	Experiential / pattern recognition- script activation Heuristics Thin-slicing (very quick decisions made with small amounts of information) Unconscious thinking theory Modular (hard-wired) responsiveness	Hypothetico-deductive Decision theory Decision analysis (arborisation) Critical, logical thought Purposeful thinking
Characteristics	Passive response High capacity High automaticity Low reliability Errors common Low scientific rigour Fast	Active response Low capacity Low automaticity High reliability Errors rare High scientific rigour Slow

the GP may be about whether hospital admission is appropriate, whereas for the physician it may be more about which test to perform to obtain a diagnosis. For Eva, the optimal CDM model is additive, in which both analytical and intuitive theories play a role, with both backward and forward reasoning [8]. This is expected to occur in novices and experts; forward reasoning is not necessarily the hallmark of expertise [8,19]. Analysis and intuition exists along a continuum in different proportions and as the analysis: intuition (A:I) ratio is increased, definition of concepts, relationships and magnitudes become more explicit and precise. Ark *et al*. showed that encouraging using pattern recognition (being told to trust familiarity) in addition to analytical methods improved performance in novice diagnosticians [79]. When novices were told explicitly to use combined strategies to diagnose electrocardiograph problems, this gave them greater diagnostic accuracy by helping overcome the difficulty provided by mention of a counter-indicative features or an incorrect diagnosis [77].

In order to provide a consistent base for teaching, Croskerry [54] proposed a model that brought together intuitive and analytical processes: System 1 (intuitive) and System 2 (analytical) reasoning. The ‘dual-processing’ account of thinking has been explored extensively in cognitive psychology [80,81] and the 2 processes shown to be anatomically and physiologically distinct. System 1 and System 2 operating characteristics are shown in Table 3. If the patient presentation is recognized, then System 1 processes are engaged. System 1 is highly context bound, fast, automatic and full of pattern recognition and heuristic mental shortcuts; it also has potential for ambient conditions to exert a powerful influence (for instance: patient appearance, communication, degree of distress, past experience with the patient, time and resources, clinician workload priority, professional and ethical issues). System 2 is engaged when the patient’s symptoms and signs are not recognized or do not follow a particular script. The approach becomes slow and analytical, uncertainty is high and hypotheses may be multiple if the complexity is high or presentation is rare. The system has 2 other important characteristics: each system may override the other with metacognition and repetitive System 2 processing leads to default System 1 processing. Croskerry suggested that rather than a discrete separation of the 2 systems, a cognitive continuum occurred with oscillation between the 2 systems.

Arguing that complex models may not be usable with the current time and resource demands on clinicians, Peile proposed a simple model for CDM [82] (see Figure 1). Intended as an instructional tool, the model consists of an expanding circle containing an increasing amount of patient information such as symptoms, signs and investigations. Simultaneously, the clinician “squares down” diagnosis and management choices using a combination of analytical approaches on the one-hand and intuitive (or values-based) approaches on the other. Actions result when the diagnosis and management choices meet the expanding patient information.

Discussion

Descriptive and normative theories of clinical decision-making (CDM) have been described in a chronological manner and the distinction between analytical and non-analytical (intuitive) models made. Current thinking suggests that analytical and intuitive models are not mutually exclusive and dual-process or additive processes are optimal for learning clinical CDM. There is a danger that the role of experience in clinical expertise could be

Figure 1 The round peg in the square hole. Simple model for teaching CDM in complex situations [82]

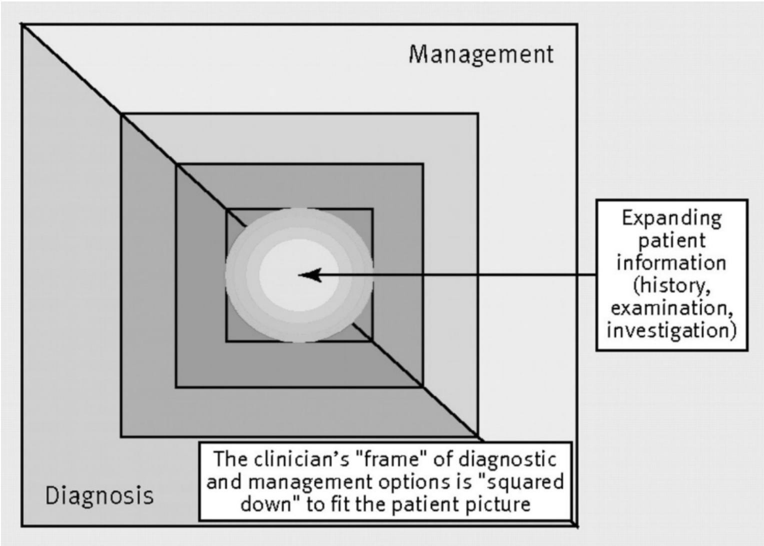

Table 4 Key recommendations for teaching clinical decision-making (CDM).

Clinician teachers can facilitate expert clinical decision-making (CDM) by:
Taking CDM seriously. Doctors have to make difficult patient decisions in uncertain or difficult circumstances, often with overall or high-level responsibility. Practical suggestions: *familiarise oneself with the role of the doctor as a professional and the implications for medical education by reading General Medical Council guidance and the Consensus statement [2].*
Encouraging development of accurate knowledge representations. Experts encapsulate biomedical knowledge into clinical knowledge representations. Biomedical knowledge is useful for an appreciation of clinical language and in novel or uncertain situations as expertise develops and should always be used in a way that promotes novices' clinical knowledge representation and in a way that mimics its eventual use. Practical suggestions: *use an integrated curriculum to teach around case examples that reflect real diagnostic and management dilemmas, using relevant biomedical knowledge only*.
Recognizing that organisation of knowledge is as important as knowledge itself. Experts organise knowledge into illness scripts, which contain encapsulated knowledge and are manifold and wide-ranging, accessible and rapidly utilised. They remain in the memory as content-specific examples and are invoked in complex situations. Practical suggestions: *an assortment of clinical cases, using prototypes as exemplars, will encourage formation of a wider range of accurate illness scripts. Reflection and elaboration on clinical cases validates the knowledge and the process*.
Acknowledging that knowledge encapsulations and illness scripts are individual constructs which cannot be transmitted; therefore each student requires active engagement. Each student will have a different knowledge bank and clinical experiences. Practical suggestions: *produce individual knowledge and experience matrices with students that will allow a bespoke but assorted clinical case mix*.
Identifying the role of non-analytical elements. Experts' script activation is intuitive and rapid, allowing richer and more accurate hypotheses to be made. Non-analytical judgement has a bearing at all stages of expertise, as novices begin to recognize patterns early on. Practical suggestions: *use prototypes that are case examples that mimic real diagnostic and management uncertainties from an early stage.*
Appreciating that a single approach to learning CDM is not as likely to be as helpful as a combined approach, which encourages development of analytical and non-analytical elements. Novices use induction and hypothesis testing which may be more longwinded and less accurate than that of experts. Practical suggestions: *Decision technologies and learning about Bayesian decision theory are likely to aid probabilistic CDM. Use simple teaching models that encourage consideration of analytical and values judgments when making decisions under uncertainty*.
Recognizing that cognitive errors are common and impair CDM. Heuristics, though often useful, are prone to error by imperfect pattern recognition. Teachers should make a positive effort to reduce cognitive bias by using cognitive forcing strategies. Practical suggestions: *Learning programmes that include metacognition (thinking about thinking) by learning cognitive error theory, an understanding of biases in clinical settings, with examples of specific biases and how to avoid them*.
Developing the current knowledge base for CDM. There is a need to evaluate teaching programmes that combine analytical and non-analytical strategies, in terms of their effect on learning and future decision-making.

dismissed as mere pattern recognition, in favour of evidence-based approaches to learning. However, it has been shown that there is a need to legitimize experiential knowledge. It has been suggested that the most important factor in learning CDM is *assortment* [6,7,83,84]; that is, to engage novices with a variety of problems. As expertise in CDM cannot be separated from content in practice, there should be an emphasis on developing clinically usable mental representations at any early stage. Even with a uniform curriculum, the mental representations and strategies that novice decision-makers will derive will be a reflection of the individual clinical experiences they have, alongside the values they retain and situational factors at the time [8]. Learners should be provided with multiple strategies that might enable them to work through a clinical problem and facilitators should recognize that learners' mental representations are highly individual and domain-specific. On this basis, key recommendations (see Table 4) for clinician teachers include: development of accurate and organised knowledge encapsulations as individual constructs, identifying the role of analytical and non-analytical elements within combined learning and reducing cognitive error by metacognition, feedback and forcing strategies.

Conclusion

This review was informed by a heterogeneous literature, both in provenance (cognitive psychology, education, clinical medicine, quality and safety) and method (theory, observational studies, narrative editorials, controlled trials, qualitative research). As such, a data metaanalysis was not appropriate. The search strategy followed established guidelines for systematic review in medical education and was limited to articles concerned with medicine, excluding articles from other healthcare professions. The justification for this is the unique role of the doctor amongst health professionals, in taking ultimate responsibility for difficult and complex clinical decisions in situations of uncertainty. The study was also limited by a paucity of evaluations of the effectiveness of CDM teaching interventions and de-biasing strategies on clinical performance. There has been a number of preliminary evaluations [85-88]; for example, Borleffs *et al*. received positive student evaluations from a clinical reasoning theatre (CRT), where clinicians' demonstrate their CDM skills by thinking-aloud with an audience of novice students. However, the impact on students' CDM skills was not evaluated [85]. Future studies will need to address the impact of tools or programmes on long-term CDM skills and clinical outcomes.

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