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Clinical cognition and diagnostic error: applications of a dual process model of reasoning

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Abstract Both systemic and individual factors contribute to missed or delayed diagnoses. Among the multiple factors that impact clinical performance of the individual, the caliber of cognition is perhaps the most relevant and deserves our attention and understanding. In the last few decades, cognitive psychologists have gained substantial insights into the processes that underlie cognition, and a new, universal model of reasoning and decision making has emerged, Dual Process Theory. The theory has immediate application to medical decision making and provides an overall schema for understanding the variety of theoretical approaches that have been taken in the past. The model has important practical applications for decision making across the multiple domains of healthcare, and may be used as a template for teaching decision theory, as well as a platform for future research. Importantly, specific operating characteristics of the model explain how diagnostic failure occurs.

Keywords Diagnostic error · Clinical cognition · Decision making · Dual process theory

Introduction

The majority of diagnostic failures, probably over 75%, can be attributed to physician thinking failure (Graber 2005). The cognitive processes that underlie clinical reasoning are complex and multifarious and have attracted considerable interest recently (Groopman 2007; Montgomery 2006). Over 40 cognitive and affective biases have been described that may impact clinical reasoning (Croskerry et al. 2008; Croskerry 2008). Not only the processes, but also the subject matter, are complex. There are over 10,000 known diagnoses, all of which are manifest to a greater or lesser degree. Some (e.g. herpes zoster) are highly manifest, their pathognomonicity presenting little challenge for diagnosis, whereas others (e.g., transient ischemic attack) may be subtle or ambiguous leading to uncertainty

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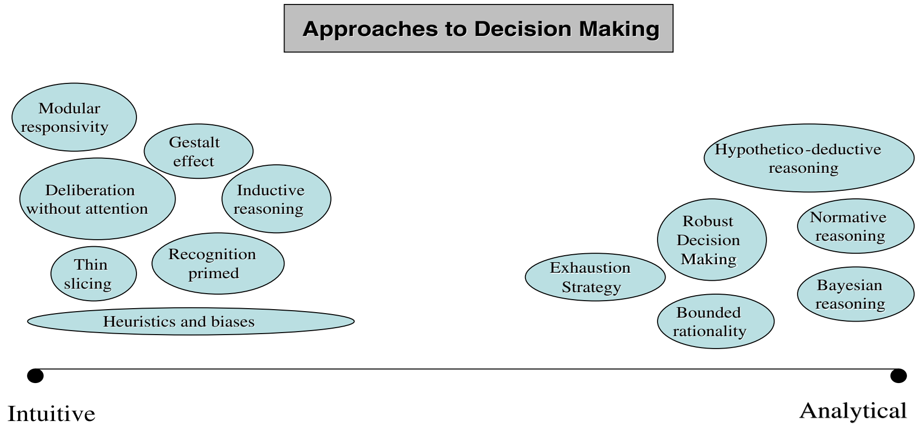

Fig. 1 Clustering of approaches on an intuitive-analytical continuum

and confusion. In medicine, as in many other spheres of decision making, there is an 'irreducible uncertainty' that will inevitably result in failure (Hammond 2000), and of all the failures in medicine, those associated with diagnosis are probably the most consequential. The particular context in which a medical decision is made is highly relevant to the reasoning process used as well as to outcome (Croskerry 2009b).

Perhaps it is this overall complexity that has led to a disproportionately wide variety of approaches towards decision making. No prevailing theory has emerged and some degree of polarization and polemics has resulted between the various theoretical camps. The critical importance of this area, nevertheless, is reflected in two Nobel prizes having been awarded in human decision making, Herbert Simon in 1978, and Daniel Kahneman in 2002.

Dual process theory

The prevailing division of opinion reflects a dichotomy that has long been recognized. In the Platonic-Aristotelian tradition of Greek philosophy, a distinction was made between an inferential mode of discursive or analytical thinking, and a non-discursive or intuitive mode.[1] The various approaches can be located along a continuum with unconscious, intuitive approaches clustering at one end and deliberate, analytical approaches at the other (Fig. 1). This clustering is now recognized as dual process theory which proposes two general classes of cognitive operations to explain human reasoning [see review, (Evans 2008)]. Characteristics of the two types of decision making are given in Table 1. Thus, there is no further need for insistence upon a single or particular overall approach to decision making; in some circumstances, an intuitive approach may be appropriate, whereas in others an analytical approach might be preferred (Simon 1990), and at times a blend of the two may be optimal. Hammond, in fact, believed there to be a continuous oscillation between the two modes (Hammond 2000).

[1] In contrast to the modern (psychological) view of intuition as an unconscious, automatic, biased process that may fall short of rationality, the ancient (philosophical) view saw it as a superior form of intelligent and rational reasoning reflecting a supreme state of mind. The change appears to have occurred quite recently in the early twentieth century, influenced by the work of the French philosopher Henri Bergson (Henden 2004).

Table 1 General properties of the two systems

Property	System 1	System 2
Reasoning style	*Intuitive*	*Analytical*
	Heuristic	Normative
	Associative	Deductive
	Concrete	Abstract
Awareness	Low	High
Prototypical	Yes	No, based on sets
Action	Reflexive, skilled	Deliberate, rule-based
Automaticity	High	Low
Speed	Fast	Slow
Channels	Multiple, parallel	Single, linear
Propensities	Causal	Statistical
Effort	Minimal	Considerable
Cost	Low	High
Vulnerability to bias	Yes	Less so
Reliability	Low, variable	High, consistent
Errors	Common	Few
Affective valence	Often	Rarely
Predictive power	Low	High
Hard-wired	May be	No
Scientific rigour	Low	High
Context importance	High	Low

Adapted from Dawson (1993), Croskerry (2005), and Evans (2008)

There is now considerable convergent support for dual process theory from a variety of sources: patients with neurological disorders associated with impaired function of the basal ganglia (Parkinson's disease and Huntingdon's disease) showed specific decrements in intuitive thinking (Lieberman 2000). Functional magnetic resonance imaging (fMRI) studies in normal subjects appear to implicate the anterior cingulate cortex in reflective thinking—for the monitoring and control of conflicting information; [see review, (Hardman 2009)]. Further fMRI studies by Lieberman have delineated areas of the brain that appear to be anatomic substrates for Type 1 and Type 2 processes (Lieberman et al. 2004), and neurophysiological studies in the macaque monkey have yielded a similar functional distinction (Buschman and Miller 2007). There appear to be genetic correlates of impulsiveness, a feature of Type 1 processing (Oades et al. 2008), and rational vs. experiential (intuitive) type thinking can be measured in personality tests (Pacini and Epstein 1999). Thus, a variety of lines of evidence from philosophy, psychology, neurology, neuroanatomy, neurophysiology, and genetics in recent years provides support for the view that decision making might best be represented by dual process theory. The theory should, then, have application to medical decision making, and, in particular, to the diagnostic process itself. Recently, a universal model for diagnostic reasoning has been proposed, describing the basic operations of the diagnostic process within a dual process framework and explaining how diagnostic reasoning skills are acquired, how they might optimally function, and importantly, how diagnostic failure occurs (Croskerry 2009a). A schematic for the model is shown in Fig. 2.

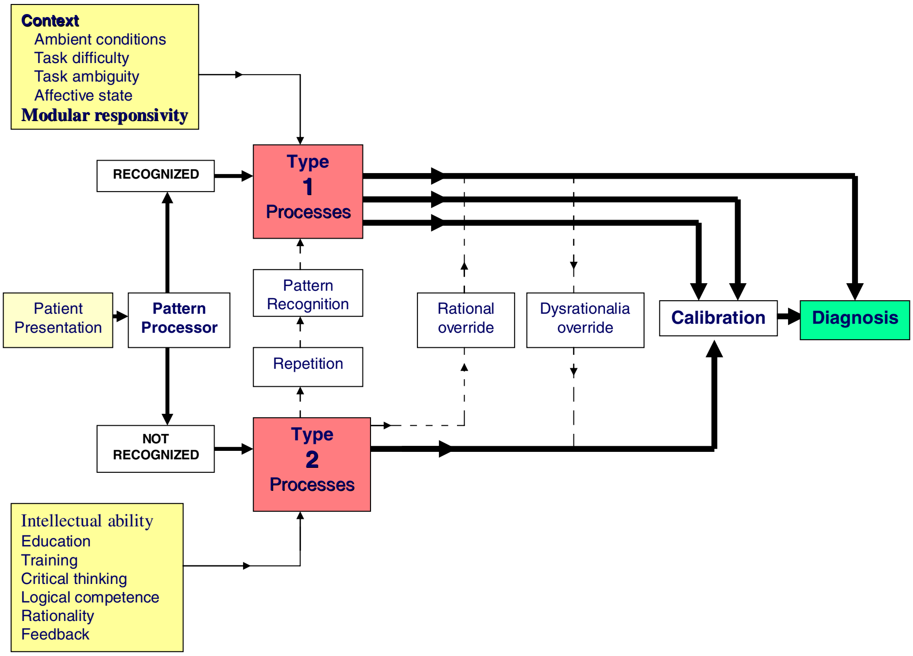

Fig. 2 Model for diagnostic reasoning based on pattern recognition and dual-process theory. The model is linear, running from left to right. The initial presentation of illness is either recognized or not by the observer. If it is recognized, the parallel fast, automatic processes of System 1 engage, whereas if it is not, the slower, analytical processes of System 2 engage instead. Determinants of System 1 and 2 processes are shown in dotted line boxes. Repetitive processing in System 2 leads to recognition and default to System 1 processing. Either system may override the other. A System 1 response may proceed directly to a diagnosis, or the outputs from both systems pass into a calibrator where interaction occurs to produce the final diagnosis. A 'cognitive miser' function prevails—the tendency to default to a state that consumes fewer cognitive resources. Adapted with permission from Croskerry (2009a)

The principle *modus operandi* of the model is pattern recognition. At the outset, the clinician accesses features of the medical condition either directly from the patient or through an intermediary (student, resident, colleague). Some conditions may be diagnosed on visual signs alone (e.g. the classic rash of herpes zoster), but others will need additional information such as a description of symptoms, and vital signs or other critical aspects of the presentation. Relatively early on in the process, it will be clear whether the condition is recognized or not. If it is, Type 1 processes will rapidly and effortlessly make the diagnosis and nothing further may be required. If it is not, then linear, analytical, deliberate and effortful Type 2 reasoning will need to be engaged instead. As noted, dynamic oscillation may occur between the two systems. Stanovich (Stanovich 2004) describes four major operating features of the model. The first three are depicted by the broken lines of Fig. 2.

1. Repetitive operation of a particular process using Type 2 reasoning may allow it to be relegated to a Type 1 level of automaticity.
2. Type 1 processes may override Type 2 for a variety of reasons including akrastic or irrational behaviors.
3. Type 2 reasoning may override Type 1 in a surveillance/governor-like fashion.
4. There is an overall tendency for the system to default to the state requiring the least cognitive effort, the 'cognitive miser' function.

Diagnostic failure

There are several loci in the model where the diagnostic process might fail. Firstly, the pattern associated with the initial presentation might be mis-identified. For example, the rash of herpes zoster referred to earlier appears straightforward, but may be mimicked, for example, by the rash of poison oak. Similarly, the constellation of symptoms and signs of nausea, vomiting, flank pain and hematuria may immediately appear to be ureteral colic but, in fact, may be a dissecting aneurysm. The clinical presentation and electrocardiogram changes of acute pericarditis may easily be mistaken for myocardial infarction. The veracity of pattern recognition depends mostly on how manifest the features of a particular disease are (i.e. its pathogonomicity), as well as on the clinician's prior experience with it. Diseases or conditions with poorly differentiated features are easily mimicked and physician calibration may suffer in consequence (Croskerry 2009b). It is important, too, to emphasize that the context in which the disease presents may have a significant impact on how it is perceived (Croskerry 2009b) e.g. patients already in hospital for observation who suffered a new acute myocardial infarction experienced longer delays to diagnosis and treatment than those who infarcted outside the hospital (Mumford and Banning 1997).

Secondly, the over-learning that occurs through repeated processing in Type 2 and allows the response to default to Type 1 might occur prematurely. With limited experience or too few exemplars, the clinician might be overconfident that the pattern is one that is recognized i.e. an error of representativeness occurs. Instead, exposure to more exemplars would satisfy the Law of Large Numbers which says that more experience will generally reveal more exceptions to the rule, and perhaps invite more caution. Another aspect of this over-learning process is that once a response has successfully relegated from Type 2 to Type 1, it may thenceforth go unchallenged and limit cognitive flexibility in thinking. Also, the ageing process is associated with a loss of Type 2 reasoning (Jacoby 1999) and a greater reliance on heuristics and affect, both characteristics of Type 1 thinking (Peters et al. 2000), and both prone to error. Well-entrenched patterns in older physicians may have lost some of their original validity over time. Many clinical areas in medicine are in a state of flux, and need periodic revision. Possibly, the clinical experience that comes with advancing age offsets, to some extent, the reduced tendency of physicians to stay current (Norman and Eva 2005).

Thirdly, the surveillance/monitoring performance of Type 2 over Type 1 may become compromised for a variety of reasons. Cognitive overload, occurring at times of extreme busyness, may diminish the capacity to provide adequate monitoring of Type 1 processes (Gilbert et al. 2003).Other factors such as fatigue, sleep deprivation, and sleep debt would similarly be expected to impair executive performance. Further, given the pivotal role of affect in decision making (Slovic et al. 2002) it would be expected that perturbations of affect would disrupt Type 2 monitoring performance (Croskerry et al. 2008).

Fourthly, there are many instances in which Type 1 processes override Type 2 reasoning in medical practice. Not infrequently, clinical decision rules are overridden in favor of individual clinical judgment, despite the overwhelming evidence that they invariably outperform the individual (Dawes et al. 2002). Similarly, overconfidence appears to underlie many diagnostic errors (Berner and Graber 2008), and has been discussed further in the dual process context (Croskerry and Norman 2008). These are examples of what Stanovich has termed *dysrationalia*, the key diagnostic criterion for which is '…a level of rationality, as demonstrated in thinking and behavior, that is significantly below the level of the individual's intellectual capacity…' (Stanovich 1993). In similar vein, *akrasia*, a term dating back to the ancient Greeks, meant acting against one's better judgment, or when, despite knowing what the best thing to do is, one does something else. Rorty has differentiated akrastic behavior further into several sub-types (Rorty 1980). Cognitive lassitude aside, these 'irrational' behaviors may account for significant diagnostic failures.

Sources of error within the two systems

The respective operating characteristics of the two processes expose them to error in different ways. Most errors occur with Type 1 and may to some extent be expected, whereas Type 2 errors are infrequent and unexpected but may be very consequential when they do occur (Dawson 1993).

Type 1 processes: depend upon two major sources of input. The first is based on modularity—the hard-wired, specialized parts of the brain that deal with specific needs of our existence e.g. parenting, face recognition, cooperative behaviors, language acquisition, foraging, anticipation of emotional states of others, and many others (Cartwright 2008; Fodor 1983). These modules exist in all human cultures and are referred to as 'universals' (Brown 1991). They are domain specific, autonomous, and have a specific neural architecture that has evolved through Darwinian natural selection, but, in the course of human development, may be calibrated to prevailing local conditions. 'We are born', says Cartwright, 'with in-built biases of perception and a priori ways of thinking'. What this means for decision making is that some Type 1 processes will depend upon modular activity, an important part of which will include the use of heuristics (short cuts, rules of thumb). Some of these will be hard-wired universals based on their adaptive value e.g. a tendency to copy the behavior of prestigious individuals in a group, or conforming to modal decision making of the group. Many of the heuristics we use appear to have such characteristics that carried adaptive, survival value in the environment of our ancestors but may now prove to be less appropriate for the complexities of modern living. Other heuristics might be learned depending upon the prevailing social, cultural, or environmental context. The problem with all heuristics is their proclivity for carrying intrinsic biases that may lead to error.

The second major source of input into Type 1 processes, as described above, is repetitive Type 2 processing. In theory, any decision process that has been repeatedly managed with Type 2 processing should become relatively error-free. For example, the continuous decision making required to drive a car is established through Type 2 processing but can eventually be relegated to a Type 1 near-automatic level, becoming a smooth error-free process unless challenged by performance limiting factors such as fatigue, sleep deprivation, or by conditions that may not have been met fully in the Type 2 acquisition phase e.g. road ice.

Type 2 processes: are deliberately used to solve reasoning and decision problems in a systematic, analytical way. They follow rules of logic and science and generally deliver error-free solutions providing that everything works appropriately, but this isn't always the case. Consider, for example, a laboratory diagnostic test that depends upon a technologically complex analyzer. All of the decisions made in selecting the appropriate test, procuring the sample, preparing it for the analyzer, and providing appropriate training for the technician who operates it, might prove futile if an incorrect calibration procedure was followed. Such Type 2 process errors may prove more consequential because a greater level of confidence is usually placed in the data they provide.

How can dual process models mitigate diagnostic error?

The universal model has obvious applications in three major areas: the realms of clinical work across a variety of domains in healthcare, education/teaching in all domains, and research into medical decision making.

1. Having a single model that explains the wide variety of decisions that are made accomplishes a major simplification of, and brings perspective to, the process. This should provide a common ground between the various schools of thought as well as a more fertile exchange of ideas.
2. The specific operating characteristics of the model can be tested for their respective appropriateness and vulnerabilities in particular clinical situations.
3. The model is straightforward and can be readily taught to learners across a wide range of disciplines. In the case of paramedics, for example, where there is a greater reliance on fast, expedient Type 1 processes, more detail can be taught about the operating characteristics of this domain and its particular vulnerabilities. For nursing, in which there has been a traditional emphasis on 'intuitive' approaches in decision making (Thompson 2009), similar insights can be gained and, when necessary, a greater emphasis placed on alternate analytical approaches. Physicians, for whom there is often an imperative to blend the two approaches in the interests of time and resources, can benefit from clear instruction on the operating characteristics of each system, their merits and disadvantages, so that an optimal calibration may be achieved for particular clinical situations under particular prevailing conditions.
4. An understanding of the model allows for more focused metacognition i.e. the decision maker can identify which system they are currently using and determine the appropriateness and the relative benefits of remaining in that mode versus switching to the other.
5. The described features of the model can generate specific research questions about decision making processes in particular situations. For example, Type 1 processes are heavily dependent on context and it would be more fruitful to examine them in this light. In contrast, Type 2 processes are relatively independent of context, so their research is less encumbered by extraneous variables. Research efforts might appropriately be directed at the obvious benefits of oscillation between the two.

Conclusions

The dual process theory of reasoning has received converging support from a variety of sources in recent years and has emerged as the dominant model for human decision making.

This development has significant implications for decision making in medicine. It establishes a comprehensive context in which a variety of historical, contrasting views of clinical decision making may be placed and their respective contributions understood. It becomes increasingly clear that particular approaches are appropriate for particular situations. The operating characteristics of this universal model provide explanations of where and how in the process, diagnostic failures occur.

The model is straightforward and suitable for teaching across all domains of medicine and provides a platform for future research into clinical decision making.

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