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REVIEW ARTICLE

"First, know thyself": cognition and error in medicine

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Abstract Although error is an integral part of the world of medicine, physicians have always been little inclined to take into account their own mistakes and the extraordinary technological progress observed in the last decades does not seem to have resulted in a significant reduction in the percentage of diagnostic errors. The failure in the reduction in diagnostic errors, notwithstanding the considerable investment in human and economic resources, has paved the way to new strategies which were made available by the development of cognitive psychology, the branch of psychology that aims at understanding the mechanisms of human reasoning. This new approach led us to realize that we are not fully rational agents able to take decisions on the basis of logical and probabilistically appropriate evaluations. In us, two different and mostly independent modes of reasoning coexist: a fast or non-analytical reasoning, which tends to be largely automatic and fast-reactive, and a slow or analytical reasoning, which permits to give rationally founded answers. One of the features of the fast mode of reasoning is the employment of standardized rules, termed "heuristics." Heuristics lead physicians to correct choices in a large percentage of cases. Unfortunately, cases exist wherein the heuristic triggered fails to fit the target problem, so that the fast mode of reasoning can lead us to unreflectively perform actions exposing us and others to variable degrees of risk. Cognitive errors arise as a result of these cases. Our review illustrates how cognitive errors can cause diagnostic problems in clinical practice.

Keywords Diagnostic errors · Decision making · Diagnosis · Medical errors

Introduction

To err is human: This is not only a renowned time-tempered statement, but also the title of a landmark report published by the Institute of Medicine in 2000 which was to drive a profound change in the history of medicine [1].

Although error is an integral part of the world of medicine (maybe even more so in our time of technology-powered medicine), physicians have always been little inclined to take into account their own mistakes, thus avoiding frank discussion and analysis [2, 3]. While the study of the various reasons behind this fact is beyond the scope of our contribution, it is interesting to point out that in other fields (e.g., aviation) the analysis of mistakes has served as a means for improvement and development [4]. More recently, the use of methods originally devised in other fields (e.g., checklists) has been proposed as a solution to tackle systematically some sources of medical errors, including the cognitive ones [5, 6].

There has always been a taboo attached to error in medical decision making as the medical profession, focused as it is on patient's health, imposed the impossibility of making mistakes. This is part of the "metaphysical halo" which has surrounded the medical profession for a long time and whose legacy is still lasting and influential.

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Later on, the modern discovery and wide acceptance of powerful mathematical and logical instruments describing reality as a world of possibilities ruled by uncertainty provided necessary conditions for the scientific analysis of reasoning and decision in medicine [7, 8]. Gauss and the normal distribution, Boole and his operators, Bayes and the posterior probability, and Galton and the regression toward the mean are but some of the brilliant characters who gave us the possibility to describe more correctly the very nature of the phenomena we observe. Unfortunately, both statistics and logic are characterized by their being often times profoundly "counterintuitive," which poses the first problem for the physician who mostly behaves as an intuitive decision maker.

Following prominent approaches, sound diagnostic reasoning has been seen as depending on a continuous recursive activity of formulation of hypotheses which are subsequently validated (or invalidated) by the presence (or absence) of their own consequences, steering the physician toward the most correct hypothesis (so-called hypothetico-deductive method) [9]. Educating the physician to the use of the most appropriate logical and statistical instruments was often considered the best strategy to streamline the decision process and reduce diagnostic errors. Moreover, in the 1980s, an effort was made to automate medical reasoning by the use of data processing systems, but this did not result in anything reliable enough to be introduced in clinical practice. At the same time, the aim to reduce the number of diagnostic errors was pursued by trying to improve diagnostic instruments, but also in this case the extraordinary technological progress does not seem to have resulted in a significant reduction in the percentage of diagnostic errors (as implied by autopsy study results over the decades [10–14]).

Cognitive errors and clinical practice

The failure in the reduction in diagnostic errors, notwithstanding the considerable investment in human and economic resources, has paved the way to new strategies which were made available by the development of cognitive psychology, the branch of psychology that aims at understanding the mechanisms of human reasoning. This new approach led us to realize that, contrary to an ancient and deep-rooted philosophical assumption, we are not fully rational agents able to take decisions on the basis of logical and probabilistically appropriate evaluations. In us, two different and mostly independent modes of reasoning coexist: a fast or non-analytical reasoning, which tends to be largely automatic and fast-reactive, and a slow or analytical reasoning allowing for responses that are founded on sound rational principles [15]. This interpretative model of human reasoning is termed "dual process framework" [16]. While the first mode of reasoning (referred to as "System 1") is always working and difficult to control, the switch to the second (referred to as "System 2") requires time and effort [17]. Since we are economical creatures by nature (someone would say "lazy creatures"), the fast mode of reasoning tends to dominate in an automatic and poorly controllable fashion.

Notably, the two modes of reasoning use two distinct neuroanatomical substrates. Functional MRI studies showed that non-analytical thinking is associated with ventral medial prefrontal cortex activation while analytical thinking is reflected by activity in the right inferior prefrontal cortex [18]. One of the features of the fast mode of reasoning is the employment of standardized rules, termed "heuristics" [19]. These "cognitive shortcuts," also defined as "rules of thumb" or "fast and frugal rules," serve the purpose of guiding our decisions in the most economical way [20]. Heuristics are utilized in a largely intuitive and automatic fashion to make daily decisions, which, in most cases, prove correct [21]. Even in clinical practice, heuristics lead physicians to correct choices in a large percentage of cases [22].

Unfortunately, cases exist wherein the heuristic triggered fails to fit the target problem, so that the fast mode of reasoning can lead us to unreflectively perform actions exposing us and others to variable degrees of risk. Cognitive errors (or cognitive biases) arise as a result of these cases. These errors are systematic and predictable and can be compared to optical illusions, which drive almost all of us to behave similarly. Indeed, the surprising feature of cognitive errors is their being predictable and systematic across culture, education, age, sex, previous experience and social extraction. A classical example is as follows: "a sheet of paper and a pencil together cost 1 euro and 10 cents; the pencil alone costs 1 euro more than the sheet of paper: how much does the sheet of paper alone cost?" [23]. The snap answer crossing the mind of everybody is 10 cents. This is wrong (the correct answer is 5 cents, because $1.05 + 0.05 = 1.10$ and $1.05–0.05 = 1$), but many accept it intuitively, and this happens also to people with a high degree of education.

These cognitive features are characteristic to all human beings, hence to physicians as well. As such, we find ourselves in a situation where not only we have to use complex and counterintuitive instruments (statistics and logic), but also we face difficulties controlling our thought. However, it must be acknowledged that, though physicians only perform modestly in decision making, their performance is better than other professionals' in other fields (e.g., economics and finance) whose choices have consequences which are often no different from sheer chance [24].

The objects of medical decisions are another problem, as the biological systems are complex by definition and the models that describe their functioning are generally rough and superficial, as our actions are consequent. Further, it must be added that patients are not static entities, but subjects whose conditions vary dynamically also as a consequence of medical decisions. Therefore, the diagnostic process does not lend itself to easy models and categories and once applied in the "real world" turns into what has been defined as "flesh and blood" decision making [25]. In the real world, we often have to face complex problems whose potential solutions can be partial, not unambiguously true or false, often with irreversible effects and with vague and sometimes contradictory goals [26, 27]. Hence, the expression "wicked problem." Rather paradoxically, the availability of powerful diagnostic and therapeutic means sharpened these problems, as it generated too large a load of information for our limited rationality to deal with in conditions of uncertainty and shortage of time.

A case

In recent years, the study of cognitive errors has had a large influence on medicine bringing together specialists in different fields [28–33]. We now know that many diagnostic errors (which result in missed, wrong or delayed diagnosis) derive from an incorrect utilization of heuristics. The number of known cognitive errors has gradually increased in the years, and comprehensive lists are available on some recently published reviews [34, 35]. In what follows, a real case report illustrates how cognitive errors can cause diagnostic problems in clinical practice.

An 81-year-old lady is taken to the emergency department because of feeling unwell with weakness, nausea and difficulties in keeping the upright position. She reports having had influenza-like symptoms 10 days before. On admission, the patient's blood pressure, temperature and respiratory function are normal.

Her medical history is notable for permanent atrial fibrillation for which no anticoagulants have been prescribed, peripheral vascular disease, and a minor cognitive decline. Over the last year, the patient had been admitted to hospital twice because of pneumonia.

Hematologic laboratory results show a modest increase in the inflammatory markers. On the basis of the recent medical history and the increase in the inflammatory markers, a chest radiograph is obtained, which is taken in a supine position. The radiologist reports a suspect left basal opacity.

Considering a possible diagnosis of pneumonia, liquids and antibiotics are administered. In the following hours, two different physicians confirm the diagnosis and continue the same therapy, even in the absence of fever and other pulmonary signs and symptoms.

About 16 h after admission, the patient presents an episode of faintness with nausea. On examination, the blood pressure recorded in the right arm is 110/50 mmHg, while no pulse can be recorded in the left. In order to rule out aortic dissection, a computed tomography (CT) with contrast is obtained, which excludes the presence of both aortic dissection and pneumonia, and shows a 3-cm abdominal aortic aneurysm with no signs of rupture.

Our patient is then transferred to the high dependency unit for monitoring. On a new examination, the difference between the two arms in the recorded blood pressure is confirmed, but it is also noticed that the left arm is colder without pain or abnormal neurological findings. At this point, an acute arterial occlusion is suspected. The radiologist is then requested to review the images of the recent CT scan, and the occlusion of the left subclavian artery is confirmed. The patient is taken to the operating theater and undergoes successful embolectomy. Following the intervention, considering the restored limb perfusion and the clinical improvement, the patient is transferred to a bed with a lower intensity of care.

However, in the following days, the patient keeps reporting that she feels unwell with difficulties in keeping the upright position. Considering the possibility of a posterior circulation stroke caused by cardiac embolism, a second CT head is obtained which shows the presence of a cerebellar ischemic lesion. Reviewing the images of the first CT head, it appears that the ischemic area was already detectable, even if much less well demarcated. The patient is then transferred to the neurology ward with a final diagnosis of cerebellar cardioembolic stroke associated with embolic subclavian artery occlusion.

Anchors and confirmations

The clinical case described above sheds light on a series of cognitive errors frequently detectable in clinical reasoning. The first diagnosis of pneumonia is formulated on the basis of weak diagnostic elements and in the absence of both fever and evocative respiratory symptoms and signs. The sheer fact that the patient had been recently admitted to hospital with pneumonia drives the physician toward that diagnosis. Therefore, s/he falls victim to the *posterior probability bias*, whereby a diagnosis is considered more likely given that it was already formulated in the past.

Another error physicians came across in this case is *anchoring*, which is the tendency to give paramount importance to the initial diagnostic evidence (which leads to the formulation of the initial diagnosis), without reconsidering it when new diagnostic elements appear during the diagnostic process. In our case, the medical history (two recent admissions to hospital for pneumonia) and the blood tests worked as an "anchor" dragging toward the diagnosis of pneumonia. It must be noticed that three consecutive physicians exhibited an anchoring bias, as no one of them formulated alternative hypotheses. Anchoring is an extremely powerful and frequently used heuristic and, according to a study [36], the most common cognitive bias among US internal medicine residents.

Anchoring can lead to medical errors not only during the diagnostic process. It can be present while evaluating the symptoms of a patient for whom a presumptive diagnosis has already been made (leading, for example, to underestimation of the degree of pain [37]). Or it can reveal itself in the moment when the physician has to decide what kind of treatment to prescribe. In a well-known study of the American Child Health Association, twenty pediatricians were requested to examine four hundred children and to indicate who of them would require tonsillectomy. Forty-five percent of the children were advised to undergo the operation. Those children who were deemed to have no indication for tonsillectomy were examined a second time by another physician, and 46 % of them were given the indication. Those children who had been deemed twice not to require the intervention were examined third time, and, again, 44 % of them were given the indication. Most probably, the pediatricians were anchored to the idea that about 50 % of pediatric patients require tonsillectomy and were not able to reconsider their therapeutic approach in light of the changing clinical scenario [38]. Lastly, anchoring can play a significant role in the process of documentary search for medical information. A physician's prior belief on a subject has a significant impact on the bibliographic search itself, and a close relation exists between pre-search and post-search answers, demonstrating that the results of a bibliographic search can reflect anchoring to preexistent beliefs [39].

Confirmation bias (to be sharply distinguished from the logical notion of hypothesis confirmation, see [40]) is a cognitive error closely related to anchoring. It is defined as the propensity to look for data confirming a diagnosis rather than data rejecting it [36]. In our clinical case, the investigations performed are aimed at confirming the initial diagnosis: The findings on the chest radiograph are useful to support the hypothesis of pneumonia, but the limitations due to the supine position and the single projection are not duly taken into account [41].

A matter of availability

Following the recording of a difference in the blood pressure between the two arms, an aortic dissection is the first diagnostic hypothesis to be formulated, while an acute ischemia of the superior limb is not considered, even after receiving the final report of the CT. The physician's reasoning seems to imply the *availability bias*, a common cognitive error which consists of considering the likelihood of a certain diagnosis on the basis of the ease of retrieval of similar examples.

As a matter of fact, the availability bias is a characteristic error of specialists, but it can also occur if a certain pathology has been recently recognized or studied, or in cases when a past diagnosis has a lasting impact on a physician (e.g., a correct or missed diagnosis which influenced the outcome of a patient [42]). Furthermore, a correlation exists between the media coverage of a certain pathology (typically an easily transmittable infection) and the use of diagnostic assays specific for that pathology. The higher the attention for a clinical event by the mass media, the easier its retrieval in the physicians' mind [43–45].

As for our case, emergency physicians are constantly on the lookout for a possible aortic dissection given the high mortality that it entails. On the contrary, although acute ischemia of the upper limb is more frequent, it is a less retrievable clinical entity (even more so when the presentation is atypical as in this case).

The importance of the frame

The radiologist reporting on the first CT study is influenced by the clinical question that has been addressed to him (to rule out or confirm aortic dissection). When clinical judgment is affected by the modality used to present a clinical situation, some variant of the *framing effect* could be present [46, 47].

This cognitive error is shown in the "myth of the phantom spider" which is well known to the emergency physicians [48]. A patient presents to the emergency department with a skin lesion of undefined origin (papule, furuncle, etc.) and asserts having been bitten by a spider. However, the patient cannot recall any bite, nor the other members of the family ever saw a spider nor the house the patient lives in is normally inhabited by spiders. Notwithstanding the absence of any evidence, the discharge diagnosis will be "insect bite." In this case, the patient himself is pushing the physician toward the wrong diagnosis, but in other cases physicians themselves risk to inadvertently divert the diagnostic process by referring an incomplete medical history. Radiologists are particularly at risk as the request for an imaging test comes with a clinical note or question. If the clinical note is incomplete or the question is not correctly put, the radiologist might find himself on the wrong track and be induced to focus on wrong details or come to a wrong interpretation of data.

Also the impact of clinical studies can be affected by the modality used to present the data. The use of relative risk rather than absolute risk mortality scales induces in the reader of a clinical trial the false perception of a larger benefit of a drug [49, 50]. In much the same way, the use of highly fascinating brain images (such as those derived from a functional magnetic resonance study), as compared to regular bar graphs, may allow to “frame” the clinical data and falsely make them more persuasive [51]. In our clinical case, the radiologist gets influenced by the clinical note and focuses on excluding aortic dissection without considering alternative hypotheses, i.e., a subclavian artery occlusion.

Satisfied by the search

The approach used by the radiologist shows another cognitive error, the *search satisfying bias* (or *satisfaction of search bias*). This error consists in the tendency to give up searching when something has been found. Unfortunately, evident findings at the beginning of the diagnostic process often represent only a small part of the whole problem or might even be fortuitous. As an old saying goes, the most frequently missed fracture by radiologists is the second one. This is to say that once the first fracture has been identified, the radiologist is satisfied and stops searching [52, 53].

A premature end

Also the diagnosis of cerebellar ischemia, whose symptoms initially led the patient to the emergency department, was delayed by a few days. After getting to the diagnosis of subclavian artery occlusion, the physicians ascribed all the symptoms to this clinical event and prematurely closed the case (*premature closure*).

Another heuristic involved in this case and commonly taught during medical school is the principle of parsimony (or *Occam’s razor*) which consists in striving to get to a unifying diagnosis while refusing to ascribe the symptoms of a patient to two (or more) distinct clinical events [54, 55]. Much as other cognitive shortcuts, Occam’s razor may help physicians when they are making decisions in the presence of multiple items of clinical information. Unfortunately, sometimes this diagnostic approach may lead to a misdiagnosis.

Does experience prevent errors?

As a distinguishing feature of cognitive errors, professional experience does not eliminate them, even if it can sometimes curb their effects. Why? According to cognitive research itself, the reason lies in phenomena limiting our capabilities to learn from observation, experience and practice.

To illustrate the relevance of reconstruction of past events as a potential source of distortion of medical judgement, let us consider two cases of the same surgical operation (e.g., a cesarean section) where an anesthetic procedure is performed (e.g., spinal anesthesia). Let us assume that the two cases are identical (clinical conditions of the patient, type of surgical operation, used drug dosage, etc.) apart from a single detail: In one case, a complication arises which determines a temporary adverse clinical event (e.g., a cardiac arrest during the operation with subsequent full recovery of both the mother and the newborn); on the contrary, in the other case the same type of complication determines a permanent adverse clinical event (e.g., the cardiac arrest causes the death of the mother and hypoxic cerebral damage to the newborn). In a classical experimental study, 21 couples of clinical cases similar to the one just described and taken from real episodes were submitted to 112 anesthetists divided into two groups. In 15 out of the 21 couples of cases, the evaluation on the performed anesthetic procedure was mostly positive (“appropriate intervention”) if the resulting damage was temporary, and mostly negative (“inappropriate intervention”) if the resulting damage was permanent [56]. Yet, for every couple, the clinical information initially available for medical decision was identical in both variants. Therefore, an adverse outcome makes the hindsight judgment much more severe than the judgment based on the same elements in case the outcome of the intervention is more favorable, determining a significant distorsion in the evaluation of the appropriateness of a clinical decision [57].

Physicians confront a multifaceted and uncertain reality, and scenarios such as the ones just described can be easily reproduced in the clinical context. For example, a physician dealing with a patient with a certain clinical picture could make a wrong diagnosis or prescribe an inadequate treatment. The observation of a positive clinical outcome, which is made possible by multiple reasons (such as spontaneous recovery), can induce him/her to deal with a subsequent and similar case in much the same way. On the other hand, an unfortunate outcome can induce a physician to unjustly question a correct diagnosis or therapy based on sound knowledge and reasoning and to alter her/his practice for the worse. *Hindsight bias* can therefore support inadequate practices and suggest the unjustified discontinuance of appropriate practices.

Learning from the past can look easy and intuitive, but, actually, it is a process full of pitfalls. In hindsight, it is relatively easy to come to the (often incorrect) conclusion that we could have judged and chosen so as to get results at least as good or even better than those observed (“I knew it all along that it would end up like this”), which boosts *overconfidence*, just another well known and pervasive cause of judgment errors [58, 59]. On the other hand, hindsight bias gets us mortified for adverse outcomes which were actually unavoidable and due to chance ("I should have known that it would end up like this") or makes us an easy target for groundless criticism ("I told you that it would end up like this"), hindering an open, constructive and rational attitude in the discussion of errors and in the systematic monitoring of procedures [60].

Conclusions

Half of a large sample of American citizens considered the suspension of the licenses of health professionals who commit errors as an effective way to improve clinical practice [3]. These data confirm a propensity by both the general public and the physicians themselves to consider medical error mainly a consequence of poor training or malpractice of the individual health professional [61]. The cognitive approach to clinical reasoning shows the reasons why this point of view is faulty. The characterization of common and diffuse cognitive errors arises from the growing understanding of the very nature of human rationality and its limits [62, 63]. A distinctive feature of these phenomena is their being predictable and systematic. Hence, if a judgment distorted by the use of a common cognitive shortcut is at the root of a medical error, removing an individual health professional from her/his workplace will make a modest contribution to the improvement of care. Most probably, the substitute will be liable to make the same mistakes. Insofar as cognitive errors play a specific role in weakening the quality of judgments and decisions in the care of patients, in order to limit their effects, we first have to acknowledge their presence and recognize their causes.

Appreciating the relevance of these results for clinical practice, some medical schools have started to include in their teaching program the study of the psychology of reasoning and clinical decision. The strengthening and extension of such an effort appear highly recommendable for any project aiming at improving the quality of care [64]. More generally, we believe that the results of the empirical investigation of decision processes, although offering a qualitatively different support from the one provided by clinical studies, are an integral part of the scientific evidence to be employed to promote appropriate decisions in the complex organization systems of contemporary medicine.

Conflict of interest The authors declare that they have no conflict of interest.

Ethical standard All human studies have been reviewed by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in an appropriate version of the 1964 Declaration of Helsinki.

Human and Animal Rights This article does not contain any studies with human or animal subjects performed by the any of the authors.

Informed Consent All persons gave their informed consent prior to their inclusion in the study.

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