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Rational error in internal medicine

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Abstract Epistemologists have selected two basic categories: that of errors committed in scientific research, when a researcher devises or accepts an unfounded hypothesis, and that of mistakes committed in the application of scientific knowledge whereby doctors rely on knowledge held to be true at the time in order to understand an individual patient's signs and symptoms. The paper will deal exclusively with the latter, that is to say the mistakes which physicians make while carrying out their day-to-day medical duties. The paper will deal with the mistakes committed in medicine trying also to offer a classification. It will take into account also examples of mistakes in Bayesian reasoning and mistakes of reasoning committed by clinicians regard inductive reasoning. Moreover, many other mistakes are due to fallacies of deductive logic, logic which they use on a day-to-day basis while examining patients in order to envisage the consequences of the various diagnostic or physiopathologic hypotheses. The existence of a different type of mistakes that are part of the psychology of thought will be also pointed out. We conclude that internists often make mistakes because, unknowingly, they fail to reason correctly. These mistakes can occur in two ways: either because he does not observe the laws of formal logic, or because his practical rationality does not match theoretical rationality and so his reasoning becomes influenced by the circumstances in which he finds himself.

Keywords Mistake · Bayesian reasoning · Inductive reasoning · Deductive logic · Psychology of thought

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Over the course of the last decade, the topic of medical error has stimulated a great deal of interest, not only among doctors and surgeons, but also among psychologists, economists and managers [1–11]. More recently still, this topic has also gained the attention of those in the fields of Logic and the Philosophy of Science. Some epistemologists who have tackled the issue of error in the field of medicine have singled out two basic categories: that of *errors* committed in scientific research, when a researcher devises or accepts an unfounded hypothesis, and that of *mistakes* committed in the application of scientific knowledge, as is the case in clinical medicine, whereby doctors rely on knowledge held to be true at the time in order to understand an individual patient's signs and symptoms [12–14]. Following on from this distinction, this paper will deal exclusively with the latter, that is to say the *mistakes* which physicians make while carrying out their day-to-day medical duties. For reasons of simplicity, however, in the text the terms 'error' and 'mistake' will be used interchangeably as synonyms.

When addressing the issue of medical error, we are faced with two different schools of thought: those who consider to be a *'mistake'* any diagnostic or physiopathologic conclusion which deviates from what is held to be *'true'*, regardless of its consequences and those who consider to be *'errors'* only those events which lead to harmful consequences for the patient [8, 15–19].

However, these errors regard the medical practice in general, and so represent that which in literature is termed *global error*. It is easy to see how global error includes a large number of events with little in common: cases in which the surgeon performs an operation incorrectly and cases in which the patient falls out of bed and injures himself while getting up at night. Clearly many of these problems have very little to do with clinical medicine in the strict sense of the term. These errors therefore, notwithstanding their importance, are not the ones which interest doctors of Internal Medicine [20–23]. Above all, physicians are interested in the errors which they themselves commit in the course of their day-to-day activities.

Medicine was dominated for about two centuries by the opinion that clinical errors could be largely attributed to the lack of, or flaws in observation; in short, doctors made mistakes because they failed to observe or pick up on certain signs, or because they misinterpreted the results of diagnostic tests.

Such an opinion is based on the conviction that the most important element in clinical methodology consists in the objective and thorough reporting of the patient's condition and his/her personal and clinical history. This conviction found a staunch supporter in Maurizio Bufalini, who, from the early 1800s, maintained that "There can be no knowledge but that which is born out of simple observation nor can there be a belief in any construct generated solely by the workings of the intellect" [24]. Following the same line of thought, Antonio Gasbarrini informed his students that "Through diligent and accurate observation one arrives at the notion of the illness: the greatest clinicians were the greatest observers" [25]; and M. Burger—a doctor from Lipsia—in his excellent Treatise on errors committed in internal medicine, instead of explicitly calling into question doctors' reasoning, attributed the various mistakes to insufficiencies in the physical examination or to the erroneous interpretation of the results of diagnostic tests [26].

In reality, however, it must be recognized that the problem of clinical error is somewhat more complex than previously stated and that the key factor involved in doctors' mistakes is not always the reporting of facts. Medicine is a scientific discipline and, like all scientific disciplines, is made up of two closely interwoven parts: an empirical part, in which real world events are observed and described, and a rational part in which various phenomena are placed in relation. Clinical errors can, therefore, derive both from mistakes in the recording of empirical phenomena and from errors in the physician's thought processes [2, 3, 22, 27–32]. In medical literature to date, little attention has been dedicated to errors in doctors' reasoning during and after the examination of the patient, yet it should be acknowledged that internists' mistakes are often due to incorrect reasoning rather than an inadequate observation of their patients. This is backed up by a recent survey which showed that out of about 100 errors in internal medicine, 28 cases were due to cognitive errors exclusively and in 74 cases cognitive errors also played a part. Moreover, the majority of these mistakes were due to problems in the elaboration of the information available, in other words in the process of reasoning based on these facts [18, 33].

The basic thesis of this paper consists in the belief that the main duty of the internist should be to reason well, that is to say to reason in a correct way. It goes without saying that reasoning is a process by which one arrives at a conclusion from an initial premise, after having elaborated certain hypotheses; not all reasoning however has the same value and from this point of view one can distinguish (1) demonstrative reasoning, (2) argumentative thought, (3) deceptive reasoning or fallacies [34–39].

Turning now to consider the aims of clinical practice, from a methodological point of view, four main goals can be identified:

(a) *to classify* our patient's diseases
(b) *to understand* the pathological phenomena in our patient
(c) *to predict* the progression of the diseases of our patient
(d) *to modify* the predicted progression using medicines, diet, physical therapy, surgery and so on.

An initial reflection reveals that errors related to the first three aims are *cognitive errors*, that is to say errors which are linked to our knowledge, and which therefore concern the question of truth. Errors related to the fourth aim, on the other hand, are *operational errors*.

Indeed, it appears obvious that a diagnosis or explanation can be either true or false, whereas a treatment cannot be false. It can, however, be inadequate, insufficient, ineffective, useless, damaging, dangerous, outmoded, misdirected and so on.

The errors committed in medicine can be classified in various ways and each classification has its advantages and disadvantages [7, 15, 18, 40]. A reasonable classification of the errors committed in internal medicine is as follows: Table 1.

Leaving aside all the other types of error, errors which have been analysed repeatedly and great in depth, and concentrating solely on errors of reasoning, it should be remembered that, following the widely accepted methodological tradition, diagnostic argumentations are based principally on calculations of probability which are in turn

Table 1 Classification of errors in internal medicine

Cognitive errors:
Errors concerning medical knowledge
Errors concerning clinical methodology
Errors of reasoning
Operative errors:
Errors in the carrying out of semiological analysis
Errors in the carrying out of therapeutical procedures
Decision making errors

based on the famous theorem set out in 1763 by the Reverend Thomas Bayes [41] (see Fig. 1).

In medicine, this theory allows us to go from calculating the probability of finding certain signs in the presence of a certain illness to calculating the inverse probability, that is to say the probability of finding a certain illness in the presence of certain signs. Bayes' theorem is considered by many to be the definitive model for rational argumentation in medicine. Indeed, after having gathered the necessary information regarding signs, symptoms, biochemical parameters, radiographic images, serologic tests and so on, each of which has a specific probability of being present in various different illnesses (probability of the pathologists) and based on knowledge of the prevalence of those particular illnesses and those particular signs in a given population (probability of the public health professionals), this theorem allows us to calculate the probability that an individual patient displaying those particular signs might be suffering from a specific illness (probability of the clinicians).

In fact, doctors often make mistakes because they misapply Bayes' theorem. Either they misjudge the sensitivity, specificity or the predictive value of a specific sign, or they do not take into account or miscalculate the prevalence of a specific illness among a specific population, or they believe that probability of the pathologists is the most important, or finally because they do not take certain pathologies into account.

A noteworthy example of error in Bayesian reasoning was expounded by David Eddy [47]. A doctor examines a patient and notes the existence of a breast lump. The doctor said (based on his experience and the literature) assesses that the probability of the tumour being malignant for a woman of her age, habits and family background is 1%, whereas the probability of it being benign is 99%. The doctor sends the woman for a mammogram and the radiographer is of the opinion that the neoplasm is indeed malignant. In terms of the diagnosis, our doctor's problem is therefore to calculate the probability of his patient actually suffering from breast cancer. He makes inquiries about the accuracy of the mammogram and discovers that this investigation correctly shows up malignant neoplasia in 79.2% of confirmed cancer cases and that benign lesions are correctly diagnosed in 87% of cases. Using Bayes' theorem, our doctor applies the following formula to his calculations:

BAYES THEOREM

$$P(M|S) = P(S|M) \cdot \frac{P(M)}{P(S)}$$

Fig. 1 Bayes' Theorem in its simplest form applied to clinical medicine

$$P(\text{ca}|\text{mammography pos}) = \frac{P(\text{Spos}|\text{ca}) \cdot P(\text{ca})}{[P(\text{Spos}|\text{ca}) \cdot P(\text{ca})] + [P(\text{Spos}|\text{Ben}) \cdot P(\text{Ben})]}$$

and concludes that the probability of his patient having breast cancer is approximately 8%.

Several doctors have been asked what the probability of breast cancer would be in one of their patients under these same conditions and the majority came up with a figure of 75%. When asked to explain how they had reached this conclusion, they responded that, given the positive outcome of the test, the probability of the patient having a cancer was roughly equal to the probability of obtaining a positive test result in confirmed cancer cases. It appears to be obvious that the doctors who gave such a response were confusing the probability of the pathologists with the probability of the clinicians, or, in other words, *retrospective accuracy* with *predictive accuracy*.

Many errors of reasoning committed by clinicians regard inductive reasoning [34–39, 42, 43].

Perhaps the most common of which is the so-called 'fallacy of statistical bias'. This consists in making inductive generalizations based on a sample which is known to be unrepresentative of the population, or a sample which cannot objectively be considered representative. In clinical practice this type of mistake happens when, for example, after having observed five subjects who have ingested a certain type of food and who show signs of a rising temperature and sweating, one concludes that this reaction is always associated with the consumption of that particular foodstuff.

A similar, yet more serious mistake is the fallacy of causal correlation, or rather the fallacy known as "post hoc, ergo propter hoc". In this case, a causal role is attributed to a certain event (event A) simply because it had preceded another event (event B) which is then seen as being influenced by the first event.

For example:

This patient has been given an antibiotic.

30 min later the patient shows signs of a pruriginous erythema of the skin located on the face and thorax.

The antibiotic was *the cause* of the pruriginous erythema.

Another mistake of logic consists in the confusing of cause and effect.

For example:

The patient is suffering from a significant polyuria.

The patient drinks a lot of liquid.

It is a well known fact that polyuria causes an increased consumption of liquids.

The patient's consumption of large amounts of liquid is caused by the polyuria.

The argumentation set out here is not at all conclusive, one would be equally justified in maintaining that the patient suffers from a polyuria caused by the consumption of large amounts of liquids.

A frequently committed error in complex cases is the so-called Petitio principii, whereby one assumes to be true that which one wishes to demonstrate.

For example:

This patient's fever was caused by the lesions brought about by an insect bite.

How do you know that the lesion brought about by the insect bite is the cause of the fever?

Can't you see that as well as suffering from a fever, this patient also has this lesion?

Indeed an extremely important fallacy in clinical practice is the so-called fallacy of division, which can be observed when, in order to formulate a diagnosis, the doctor relies on differential diagnosis. As we know, differential diagnosis is based on the disjunctive syllogism. The reasoning usually used in differential diagnosis can take one of the two following forms:

I

The patient P is suffering from illness M1 or illness M2 or illness M3

The patient is not suffering from illness M1 nor illness M2

—

The patient P is suffering from illness M3

II

The patient P is suffering from illness M1 or illness M2 or illness M3

The patient P is suffering from illness M1

—

The patient is neither suffering from illness M2 nor illness M3

Both of these processes are subject to the fallacy of disjunction when the number of illnesses from which the patient might be suffering is greater than the number of illness effectively taken into account. In fact, if one affirms that:

P's precordial pain could be due to a myocardial ischemia or an aortic aneurism disruption

and one does entertain the possibility that this pain might also be due to an acute viral pericarditis or a oesophageal disease then the demonstration of a myocardial ischemia or the demonstration of the absence of a aortic aneurism disruption could lead to an incorrect conclusion.

Moreover, if the separation on which the second argument (II) is based is an inclusive (or weak) disjunction, then the premiss simply affirms that at least one of the possibilities put forward is true. As such, the patient might be suffering from illness M3 *and* illness M1, or by illness M3 *and* by illness M2 [44].

Although many of the errors committed by physicians are due to erroneous Bayesian calculations, many other errors are due to fallacies of deductive logic, logic which they use on a day-to-day basis while examining patients in order to envisage the consequences of the various diagnostic or physiopathologic hypotheses.

In order to illustrate these errors, errors which are often committed unwittingly, we will now consider some simple deductive arguments which are partly valid and partly invalid:

All feverish individuals are tachycardic (t)

All those with pneumonia are feverish (t)

—

All those with pneumonia have tachycardia (t)

Clearly both of the premisses in this deduction are true, the conclusion is true and the deductive argumentation is valid.

Let us now turn our attention to another deductive inference:

All feverish individuals have hypertension (f)

All those with hypertension have tachycardia (f)

—

All feverish individuals have tachycardia (t)

In this second inference, the premisses are false, the conclusion is true but the argumentation is identical to the previous one and the deduction is, therefore, perfectly valid.

Now let us consider a third deductive inference:

All feverish individuals have hypertension (f)

All those with tachycardia have hypertension (f)

—

All feverish individuals are tachycardic (t)

Also in this case the premisses are false and the conclusion is true. The conclusion however, despite being true, is not guaranteed by the premisse and so, therefore, the deduction is not valid.

Now let us ponder a fourth inference:

Some feverish individuals have tachycardia (t)

Some individuals with pneumonia are feverish (t)

—

Some individuals with pneumonia have tachycardia (t)

In this case the premisses and conclusion are both true, but the conclusion is not guaranteed by the premisses and so, therefore, the deduction is not valid.

And so turning to a fifth deduction:

Some individuals with pneumonia have hypotension (t)
All individuals with pneumonia are feverish (t)
—
Some feverish individuals have hypotension (t)

In this case the premisses and the conclusion are both true and the deduction is valid.

Some fundamental conclusions can be drawn from these examples of deductive reasoning:

(a) it is an error of logic to infer the truth of the premise from the truth of the conclusion.
(b) it is an error of logic to infer from the truth of the conclusion the validity of an argument.
(c) it is an error of logic to infer from the falsity of the conclusion the invalidity of an argument.
(d) it is an error of logic to infer from the falsity of the conclusion the falsity of the premise.

Applying these general conclusions to clinical logic, it can be affirmed that:

(a) based on a true diagnosis it cannot be concluded that the initial premise were true
(b) based on the truth of the diagnosis, it cannot be concluded the reasoning was correct
(c) based on an incorrect diagnosis, it cannot be concluded that the reasoning was incorrect
(d) based on an incorrect diagnosis, it cannot be concluded that the initial observations were false

The deductive argumentations which we have been looking at until now concerned classes of individuals and were aimed at affirming that a specific characteristic can be attributed to a given class, or at least to a part of the individuals that make up that class: for example the characteristic of fever to those suffering from tachycardia or the characteristic of tachycardia in those suffering from pneumonia.

There are, however, other deductive argumentations which do not regard the attribution of characteristics, but which aim to confirm or refute a given hypothesis. Some of these deductions clearly constitute fallacies. Among these, probably the most common deductive fallacy is the fallacy of confirmation, or the fallacy of the affirmation of the consequent. Here is an example:

If this patient is diabetic, he will therefore display signs of glycosuria
This patient displays signs of glycosuria
This patient is therefore diabetic.

Clearly this argument is not valid as the patient with glycosuria might not be diabetic at all and could instead be suffering from thyrotoxicosis renal glycosuria, or pyelonephritis and so on.

Another common fallacy in present doctors' reasoning is the fallacy of the denial of the antecedent. This is illustrated in the following example:

If this patient's slight fever disappears following anti-tuberculosis drug treatment, the fever is therefore due to a tubercular infection.
The fever does not disappear following the anti-tuberculosis drug treatment.
Therefore the patient is not suffering from a tubercular infection.

As has been demonstrated, errors of reasoning can take many forms. In other words, we can err in many different ways and often we do not realize that we are doing so, we take for conclusive argumentations which are nothing of the sort, which, at best, provide a very weak support for our affirmations or our hypotheses. Herein lies the sneaky way with which errors creep into our minds: we are convinced that we have finally reached a *diagnostic truth* or a *true* physiopathologic explanation, whereas in fact we have simply been chasing a shadow.

Until now, we have considered the errors of reasoning committed in clinical medicine. Now it is necessary to point out a different type of errors that are part of the psychology of thought. In recent years, in fact, a new field of research has developed which analyses the way in which experts, such as doctors or stockbrokers, and non-experts alike carry out reasoning tasks [39, 45–47].

This research has shown that in practical reasoning tasks humans commit many logical errors and that the participants' responses are greatly influenced by the problem context and its content, despite the logical irrelevance of these aspects. Studies by Tversky and Kahneman have led to the conclusion that human rationality is limited by cognitive conditioning. In a situation of uncertainty, this cognitive conditioning leads the decision maker into using simplification strategies—known as heuristic choice—which are linked to systematic errors of judgement. Even the experts are not immune to this tendency and in various applied situations move away, to a greater or lesser extend, from the formal rules of logic [48].

These errors in applied tasks of reasoning are profoundly different from those we have considered until now; while the aforementioned represent errors of logic, errors that is which derive from the failure to observe the rules of thought, the mistakes which we are about to discuss depend on the way in which the problem is presented (framing). In order to illustrate this we will look at just two examples.

When a physician has to formulate a diagnosis, he puts forward a certain number of hypotheses and assigns a certain probability to each one of these. For example, faced with a case of precordial chest pain he conjectures that his patient might be suffering from ischemic heart disease or pericardial pain or aortic aneurysm or an abdominal pain radiated to the thorax. A group of doctors were asked to assign a probability to each of these hypotheses. Their responses were as follows: ischemic pain was given a 55% probability, pericardial pain a 5% probability, aneurysm related pain a 10% probability and abdominal pain a 30% probability. As required by the theory of probability, the sum of these figures is 1. The same group of doctors, faced with an identical case of precordial chest pain, were given a similar task of assessing the probability for each one of the illnesses in same set as before. On this occasion however, ischemic pain was divided into 3 subgroups: acute myocardial infarction, angina during exertion and unstable angina. The second part of the experiment brought some unexpected results, by dividing the general heading of ischemic pain into 3 subgroups, the sum of the probabilities assigned to these subgroups was greater than the probability assigned to the general heading under which they were included, whereas the probability of the remaining hypotheses (pericardial pain, aneurysm, abdominal pain) remained unchanged. As such the total probability of all the hypotheses combined paradoxically became greater than 1. This experiment shows that when the spotlight is turned onto a specific diagnostic hypothesis, one which had previously been overshadowed under a wider umbrella hypothesis, and a specific probability is assigned to this hypothesis, doctors often fail to review the probability of the various remaining diagnostic hypotheses. This inevitably leads to miscalculations [49].

Let us look at another experiment. The following situation is described to a group of doctors: a doctor is called upon mid-flight to examine a 60-year-old passenger who has been suffering from an intense precordial chest pain. The First Aid kit contains a sphygmomanometer, which gives a SBP reading of 120 mmHg. The group of doctors are asked whether they would recommend an emergency landing or whether the flight should continue. The majority of doctors (89%) reply that it was mandatory to go back asking for an emergency landing.

In the second part of the experiment the doctors are confronted with the same scenario, except this time the First Aid kit does not contain a sphygmomanometer. The cabin crew are sure that they have seen it and insist on conducting a search. This extensive search leads to the discovery of the apparatus. The SBP is finally measured and a reading of 120 mmHg is obtained. The doctors are asked the same question as in the first scenario. Their response in this case differs from the previous one, even though both situations are essentially the same. In the second case a greater number of doctors (85%) recommended that the flight should continue.

This second experiment shows that the importance given to a clinical sign varies depending on whether it comes to light immediately or whether it is discovered thanks to a deliberate and determined search [50].

The results of these and many other psychological experiments throws new light on doctors and their rational performance. It has always been maintained that in their daily lives people’s beliefs, and also those of doctors, are clear cut and unchanging over time. It has also been maintained that the acquisition of new information could but improve our suppositions about reality and our ability to arrive at an affirmation of the truth. In reality, psychological studies based on practical reasoning tasks show that the situation is really not that simple: doctors are not impartial with regards to their beliefs, these beliefs are not always clear cut and are not constant over the course of the investigation. On the contrary, often these beliefs are actually formed during the investigative and decision making process. As has been stated “individuals’ priorities are subject to change and a small difference in circumstances can sometimes alter people’s preferences and led them to make alternative decisions”.

All things considered, we can conclude that internists often make mistakes because, unknowingly, they fail to reason correctly.

In the past, it was thought that the errors committed in medicine were essentially due to defective or incomplete observation and that once doctors had learnt to ‘observe well’ they would be safe from committing errors. Unfortunately, this is not the case.

Even after an internist has carried out a thorough and correct examination of his patient, he can still make a mistake. These mistakes can occur in two basic ways: either because he does not observe the laws of formal logic and so falls into the trap of one of the many fallacies which logic shows us how to avoid, or because his practical rationality does not match theoretical rationality and so his reasoning becomes influenced by the circumstances in which he finds himself.

Science—it has been said—is fallible because it is human. This is beyond doubt, yet it should be added that clinical medicine is doubly fallible: both because it is the work of man and because these men must intervene to resolve the problems of others in emotionally demanding circumstances.

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