MEDICINE AS A SCIENCE OF DESIGN*

La medicina como ciencia de diseño

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ABSTRACT

There is a long dispute in the philosophy of medicine between those who consider medicine as an applied science and those who defend that is an art. We defend an alternative: medicine is a science of design. Doing this allows us to introduce prescriptive and evaluative elements that are generally analyzed in a constructivist way, as well as a reconsideration of rationality in terms of bounded rationality and evaluative rationality.

Key words: bounded rationality; evaluative rationality; prescription; applied science; basic science; *techné*.

RESUMEN

En filosofía de la medicina hay una discusión, que viene desde lejos, entre aquellos que consideran que la medicina es una ciencia aplicada y los que opinan que es un arte. En este artículo se defiende una tercera posibilidad,

analizarla como una ciencia de diseño. Esto nos permite incorporar aspectos prescriptivos y evaluativos que por lo general se analizan desde perspectivas constructivistas, y nos conduce también a una reconsideración de la racionalidad en términos de racionalidad limitada y racionalidad evaluativa.

Palabras clave: racionalidad limitada; racionalidad evaluativa; prescripción; ciencia aplicada; ciencia básica; *techné.*

1. INTRODUCTION

Is medicine a science… or is it an art? These questions, and the variety of ways of answering them, form the backbone of a great deal of philosophical thinking about medicine. This article, however, investigates a third possibility: that medicine can be viewed as a science of design, as proposed by Herbert Simon and Ilkka Niiniluoto.

To this end, we turn to a threefold consideration. First, the history of medicine shows that it was an art cultivated by people whose aim and objective were the preservation of health and the avoidance of harm and pain (objectives that remain almost intact to this day), but whose knowledge was based on a characteristic worldview. This remained the case, with very few differences, for many centuries until the Scientific Revolution of the 17th century. Then, especially with the work of authors such as Vesalius, the received conception of medicine as the art of maintaining the inner balance of certain bodies in harmony with the environment in which they live, changed to a mechanistic conception in which the restoration of health was based on laws and principles of general application. This process of moving from a technique to a science is what Niiniluoto describes as a process of scientization and mechanization of the arts (1993) specific to the design sciences. The properties that Niiniluoto confers on the design sciences allow us to understand medicine as an eminently practical and not purely theoretical activity, since emphasizing the scientific side of medicine can make us forget the practical component that still remains in medicine.

Second, the rationality inherent in the design sciences is a bounded rationality, in the sense that it is not possible to seek the optimal solution, but only the one that is good enough. This has to do with the limited computational capabilities of human beings, in this case physicians, but also with the type of problems they face. Anna Estany, based on Lawson 2006, refers to wicked problems, i.e., «those in which the person who has to solve the problem does not have access to all the necessary information and where

the problem is formulated ambiguously, and the formulation of the problem itself is transformed as the search for the solution progresses. Thus, the wicked problems do not admit an exhaustive analysis and for which we never have the guarantee of having found the perfect solution». (Estany, 2021, p. 13) This, although originally referring to design issues, perfectly reflects the physician's position when faced with a diagnosis or the establishment of a treatment.

Third, some authors, such as Nigel Cross, characterize design on the basis of objective, method, but also values. Cross (2006) cites practicality, empathy, and appropriateness as characteristic values. These are non-epistemic values, necessary to make a good decision, but completely different from the prevailing epistemic values in science.

The idea guiding the present paper is therefore that medicine is better suited to the characteristics of the design sciences, given the three domains outlined above and that design sciences allow us to account for both the practical and theoretical components that characterize medicine and also make it possible to approach the eternal science-art discussion from a conciliatory and non-exclusive perspective.

2. MEDICINE AS A SCIENCE OF DESIGN

According to traditional thinking, medicine has a twofold nature: firstly, it requires fundamental research and clinical studies to be carried out; yet undeniably, an essential part of medicine is personal, personalised interaction with patients. Those who attach greatest importance to the scientific aspect of medicine tend to describe it as applied biology; their views are grounded in scientism, biologism or reductionist mechanicism (see Philip Kitcher 1997).

Yet within this all-encompassing response, there is another option – one which has been less thoroughly explored: that at least some part of medicine can be viewed as a *science of design*. Herbert Simon advanced this theory in his seminal 1981 work, and it was once again espoused, some years later, by Ilkka Niiniluoto (1993). Simon defines sciences of design as those sciences «concerned with how things ought to be in order to attain goals, and to function» (Simon 1996, 4). In the eyes of both these authors, design is understood as a human activity, undertaken to produce, prepare or manipulate systems (be they natural or artificial). The objective of research in sciences of design is to improve humankind's abilities in the domain at hand (what the Greeks would describe as *techné*). Therefore, the knowledge produced is an instrumental type of knowledge, destined for use in a pre-defined activity. Thus,

the view of medicine as a science of design sits between the two extreme poles mentioned above – medicine as applied science and medicine as an art.

Niiniluoto distinguishes a range of medical activities: (i) the medical profession (that of a physician); (ii) medical practice (therapy or healing); (iii) the art of medicine (the skills and abilities needed for this practice); and (iv) medical science, which is what would, in the strictest sense, be defined as a science of design, the aim being to improve medical capabilities. This division also indicates that healthcare workers specialise in different domains: a practitioner of the art of medicine does not necessarily need to conduct research, though they reap the benefits of such research. In Niiniluoto's view, the science of medicine is the result of the scientification of these other areas of professional activity. Thus, chronologically speaking, prior to its advent as a science of design, medicine already existed in its other three forms: as a profession, as a practice and as an art. From a historical point of view, medicine as a science of design is a far younger domain than the other three branches.

For examples of these different medical activities, let us look at the COVID-19 pandemic: (i) first, we have the medical profession – those who have dedicated themselves to caring for COVID-19 patients; (ii) next, we have medical practice, which yielded the discovery that the respiratory capacity of many intubated patients improves if they are placed in a prone position; (iii) the art of medicine lies in identifying those patients whose breathing is improved by that technique; and (iv) the science of design provides the knowledge which elucidates why this position produces an improvement: it allows better aeration and helps blood flow to the lungs.

A cornerstone concept in sciences of design is *prescription*, understood as the establishment of guidelines on what action to take in order to solve problems (González 2007, 3), which is absolutely characteristic of this type of sciences. In the case of Niiniluoto, such prescriptions take the form of technical standards: «If you want A, and you believe that you are in situation B, then you ought to do X» (Niiniluoto 1993, 12). Years earlier, Whitbeck (1977) pointed out that explanations in medicine are closely linked to our own instrumental interests in predicting and monitoring the results of our actions. On the other hand, it must be recognised that prescription includes a normative component – it indicates what must be done to change a current situation, to bring about a different situation, deemed preferable. This is all the more evident in the case of medicine, because the normative component includes implicit evaluative elements in regard to what is preferable – from a practical standpoint, but from a social, cultural and moral one as well. As Cristian Saborido points out, «medicine is normative as well because it is

founded on evaluative suppositions that were established prior to its being put into practice» (Saborido 2020, 142).

According to Niiniluoto, if the prescriptions – or, where applicable, the technical standards – are founded on knowledge gleaned from descriptive statements stemming from basic research, then sciences of design are applied sciences (Niiniluoto 1993, 13). However, a technical standard may also be constructed from the ground up – by way of modelling, trial-and-error and experimentation. Given that sciences of design and applied sciences alike predict possible futures and lay down guidelines for action in the case of specific problems, one may wonder whether there is a unique element to sciences of design which sets them apart from applied sciences. Simon tells us that there is: sciences of design are sciences of the artificial – artificial being understood in opposition to the natural, and as something that is man-made. More specifically, «certain phenomena are «artificial» in a very specific sense: they are as they are only because of a system's being molded, by goals or purposes, to the environment in which it lives» (Simon 1996, xi)[1]. Thus, as Niiniluoto holds, sciences of design are on a continuum along with applied sciences, though they are in a special category, as they also belong to the class of sciences of the artificial. We, unlike Niiniluoto, hold that this is not a linear relationship: that is, that feedback takes place between fundamental science and applied science. In addition, it is our belief that, in most cases, it is impossible to place the different types of research on a linear model, where basic science serves as the foundation for applied science, which in turn serves as the foundation for sciences of design, as this system does not reflect the reality of scientific practice.

Medicine, then, draws on knowledge from fundamental sciences such as biology and biochemistry, to produce instrumental knowledge that can be used to manipulate systems, but it also draws on knowledge from applied sciences. Looking at Niiniluoto's model, this implies that medicine is split: not all of medicine can be described as science of design. Niiniluoto points out that

> the border between descriptive and design science splits many scientific disciplines (…) *Basic research* about S (for example farming or nursing) tries to describe the present state of S and to establish some systematic regularities about S – in this way, we may speak about basic research within technical sciences, life sciences, medicine, social sciences and jurisprudence. Design science contains only a part – the practical kernel, so to speak – of these disciplines (Niiniluoto 1993, 14) (our emphasis).

1. We shall see, later on, that this has a great deal to do with the historical and contextual nature of diseases.

In the case of medicine, that split can be understood from the standpoint of the difference between clinical and preclinical medicine. The former deals with diagnosis and treatment of disease in patients, and includes both clinical practice and clinical research.[2] Preclinical medicine, on the other hand, entails research into the function and structure of the human body – exclusively research, with no direct intervention on patients (Sadegh-Zadeh 2012, 765). From our point of view, clinical medicine would be understood as a science of design, as it generates instrumental knowledge for the treatment or prevention of diseases, and obtains a portion of fundamental knowledge from preclinical medicine, obtaining the remainder from clinical research.

Thus, we might have a propositional statement such as «Gamma rays affect cell DNA, causing strand breaks, and thus prevent tumour cells from reproducing», stemming from clinical research[3]. On the basis of that statement, a technical standard can be devised, whereby: «if you wish to destroy a tumour, then you should administer radiotherapy to the patient».

In Niiniluoto's view, a component included in the first part of all technical norms depends on the objectives of the science at hand. If the goal of medicine is to promote health (Niiniluoto 1993, 15), then the norm should be reformulated as follows: «If we wish to maintain the patient's health, we must do X (in the case at hand, destroy the tumour)». The form of this norm is based on a set of reflections which can more accurately define whether medicine include elements of science of design. The rest of this article is devoted to this goal. To begin with, we discuss just what is meant by health and disease. Then, we look at whether science of design can be distinguished from medicine as an art. Next, we analyse which types of rationality are involved in medicine as a science of design, and demonstrate that these issues are closely tied in with that of prescription and evaluation, which is the cornerstone of medicine.

3. SAFEGUARDING HEALTH AS THE OBJECTIVE OF MEDICINE

The conceptualisation of health and disease has shifted over time, as these concepts are open to evaluative questions. In philosophy of medicine, there

2. «Clinical research is an activity aimed at discovering the result of a course of action or a product for diagnosis or treatment in humans» (Marañón & León 2015, 165).
3. Of course, clinical research is, in turn, founded on fundamental science, but not in a linear fashion. For the distinction between fundamental and applied sciences, see González 2015, 32-40.

is heated debate about this conceptualisation between «naturalists» and «constructivists». In the eyes of the naturalists, in order to define what a disease is, we must take account of what is biologically natural and normally functional for all human beings, or at least for members of a class within an age group or gender. In their view, health is the absence of disease, where disease is an internal state that prevents the organism from functioning normally. However, as indicated by Tristram Engelhardt (1975 127), the concepts of health and disease include both descriptive and evaluative aspects, and are action-orientated. In order to circumvent the question of evaluation, Christopher Boorse (1997) proposed a biostatistical approach, intended to be objective. Health is held to be the absence of disease; disease is viewed either as an internal state which disrupts normal functional abilities, or as a limitation of functional abilities because of the environment. In order to understand precisely what «normal function» is, reference must be made to a class that is the natural class of organisms, for example, within a specific age group and gender. Thus, a process or a part –e.g. an organ– functioning normally makes a statistically typical contribution to the individual's survival and reproduction. Hence, «normal» is what is «statistically normal». This view, which is very widespread among objectivists and naturalists, has been criticised by Ronald Amundson (2000) and Rachel Cooper (2002), among others, who point out that it is not easy to establish what is «statistically normal». For example, statistically speaking, homosexuals are in the minority, and could therefore be considered a «deviation from the statistical norm», and that sexual orientation prevents these individuals from reproducing «naturally» – thus, such behaviour would represent a limitation of functional abilities. In fact, similar arguments were why, for many years, homosexuality was classed as a mental disease. This is because, in reality, a biostatistical approach is also based on an evaluative concept, equating what is «normal» to what is «statistically normal» (Ereshefsky 2009). However, nothing in biology supports these conclusions, as there is nothing which can be considered «absolutely standard in the design of a species», even in terms of subgroups relating to age or gender.

For constructivists, it is a much more complex matter to define health and disease, as it is explicitly recognised that these concepts also depend on normative judgements and the devising of appropriate terms to describe such conditions. In this context, the state of health is held to depend on shared values in terms of what is assessed positively, while disease is something which goes against those social, cultural or moral norms. This framework more easily accounts for the fact that homosexuality was, up 1974 classed as a disease, in the *Diagnostic and Statistical Manual of Mental Disorders*. This

change can be understood in the context of the social changes and shifting values in many modern societies.

In any case, as Niiniluoto points out, all views of what is considered health and what disease share an underlying prescriptive frame of reference, whether the two concepts are defined from a biostatistical or constructivist point of view. How we define health and disease depends on guidance to undertake actions in order to achieve an objective deemed valuable, though that objective itself may vary over time, from one society to another, and even from one individual to another. It may range from preventing suffering to regaining certain lessened capacities, or overcoming the physiological changes which occur throughout life.

4. THE ART OF MEDICINE

In the different categories he puts forward to assess exactly what medicine is, Niiniluoto reserves a special place for the exercise of medicine, which he describes as «the art of medicine»; the objective of the science-of-design aspect of medicine is, specifically, to improve the art of medicine. Thus, he resolves the age-old dispute between those believing medicine an art from those believing it a science.

Niiniluoto's system draws the distinction between practice (therapy, treatment, healing) and the skills necessary for that practice, but the concept of *ars* or *techné* has implicitly included that practical aspect throughout its history. Technique (*techné*), in the Greek sense, is practical ability which obeys certain rules in order to achieve a specific objective. However, rather than being an ability to think, it is an ability to take action. It was Aristotle who, in his theory of knowledge, first included and took account of technique. In *Metaphysics* and more broadly in *The Nicomachean Ethics*, he discusses the matter and includes it alongside other forms of knowledge (along with *Phronesis, Episteme, Nous* and *Sophia*), all of which depend on experience (*Empeiria*). Human beings are capable of «making» things, which the Greeks refer to as *poiesis*. However, rather than making things, *techné* entails *knowing how to make them*. In fact, Aristotle uses the example of medical knowledge. The knowledge that a remedy has healed someone is empirical knowledge, gleaned from experience. Yet the knowledge that the same remedy cures bilious disorders is no longer experience – it is *techné*. While experience is the knowledge of specific things, medicine as technique is knowledge in a general sense – knowledge of cause. Through experience, Aristotle tells us, we can know that something exists without knowing *why* it exists, but

with medicine, we know the why: we know the cause. In addition, someone in possession of such knowledge may impart it and teach it. In so doing, he underlines the fact that such knowledge is not tacit (as knowledge derived from experience might be), but rather, is taught and learned with specific language attached. However, it is not elevated to the lofty level of *episteme*, which could be expressed, clumsily, in modern language as «science». This may be due to the fact that Aristotle's idea of *episteme* also differs enormously from what would be understood as science today. In fact, it is important, in medical technique, to include large doses of *Phronesis* (usually translated as «prudence») – another of the forms of knowledge which Aristotle discusses. To cite Saborido:

> For Aristotle, phronesis represents a combination of theoretical and practical knowledge, along with a normative perspective: to determine the correct course of action, we need to have adequate knowledge of the world, have the ability to act upon it by means of our decisions and, furthermore, be able to rationally consider the desired consequences or effects of our actions (Saborido 2020, 145).

Thus, over the centuries, conventional philosophical thinking about medicine has gradually divided into a dual concept. It is understood in its most empirical form (the practice of medicine as an art) and medicine as a science, in the sense of knowledge of causes, identified by Aristotle as *techné*. The 17th century saw the dawn of the hybridisation, which became pronounced by the 19th century. In 1828, Johann Wilhelm Heinrich Conradi wrote:

> Medicine is to be considered as a science (a science of healing, a science of drugs) insofar as it presents a mass of knowledge, traces this knowledge back to basic principles and derives it from them, insofar as it orders this knowledge and presents it in a systematic fashion. It is an art (an art of healing, an art of prescribing drugs), however, insofar as it consists in the capability of acting according to particular rules (*apud* Wieland 1993, 168).

Is it possible, in today's world, still to hold that there is such a thing as the art of medicine? If so, how does this fit in with Niiniluoto's and Simon's thinking? Wolfgang Wieland highlights three aspects that continue to be part of the art of medicine: (i) firstly, the doctors» skill and dexterity – for example, the skill that it takes to perform an endotracheal intubation.[4] (ii) Secondly,

4.   «Endotracheal intubation requires certain knowledge and manual skill to be performed successfully, and for patients to survive», and «To attempt to intubate a patient

according to Wieland, we have clinical judgement, which is the result of experience in medical practice, though to a degree, this experience can also be obtained through more formal training. Turning again to the example of endotracheal intubation, such a move may be required in a range of situations: cardiorespiratory arrest, the need to prevent blockage of the airway, cranioencephalic trauma, acute respiratory failure, etc. Clinical judgement lies in being able to identify which of these general principles applies to the individual patient at hand (Ostabal 2002, 335). (iii) Thirdly, as Wieland points out, intuition and instinct play an important role, when only limited information is available and the doctors have to make a decision, through necessity. At times such as this, normative decision-making theory does not apply, and therefore, it is paramount to be able to draw upon one's intuition. Stuart F. Spicker makes a similar point:

> we can at most safely conclude that the role of intuition in medical diagnosis, even in our era of sophisticated medical technology, is nothing less than an admission of our insufficient and tentative knowledge, but where, nevertheless, physicians are still compelled to act, and where what is understood as intuition is necessarily opaque (Spicker 1993, 207).

Others view intuition merely as a subconscious inference, subject to critical assessment (Moseley 1993). There are also those who use the term «*intuition* to distinguish between following the rules of scientific methods from [sic] a personal insight» (Sassower 1993, 221).

The skill and dexterity which doctors develop may be seen as a form of «know-how», acquired through practice. In fact, owing to the risk inherent in performing certain actions without the requisite skill, when students are beginning to learn such skills, they tend to practise on dummies rather than on live human beings. The shift to working directly on patients tends to be a very gradual, drawn-out process, requiring lengthy periods of training and supervision by a professional who already has the skill. The application of this know-how is quite distinct from other cases, where the knowledge does not pertain to human beings, or from situations not requiring stringent safety measures to be observed. Here, we again see the prescriptive-evaluative element of which Niiniluoto speaks. On the other hand, the intuition to which Wieland refers, which is certainly in evidence in medical practice, can also be acquired through such practice. It can therefore be viewed as tacit knowledge which is the product of repeated experience with similar cases. This

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without prior experience, or without supervision from someone who has experience, is an aberration» (Ostabal 2002, 335, 337).

aspect is common to many types of practical intervention in the world, which is difficult to express in propositional language, and therefore, is generally more closely associated with practice than with more theoretical scientific elements. Nevertheless, in exercising «clinical judgement», reference must be made to technical guidelines produced by medicine as a science of design. Returning once more to our example, clinical judgement would be exercised on the basis of a prescriptive statement such as: «if we wish to maintain the patient's health], in the event of cardiorespiratory arrest/cranioencephalic trauma/acute respiratory failure, perform an endotracheal intubation». Still, undeniably, in most cases, clinical judgement as to whether an intervention is needed is exercised in situations with limited knowledge and resources – that is, in situations of bounded rationality.

5. BOUNDED RATIONALITY

A fundamental notion in Simon's thinking about sciences of design, with which Niiniluoto agrees, is rationality. Rationality comes into play both in the design process and in human operators» application of the resulting designs. As noted previously, sciences of design provide knowledge, which can be applied in constructing strategies for action, guided by prescriptive principles. In the case of clinical judgement, doctors are required to take decisions – i.e. to make choices. Take the example (drawn from (Gigerenzer 2005)) of a patient who has come to the hospital suffering chest pains. The doctor needs to decide whether to send the patient to the coronary unit or keep him under observation, and also which tests to order. This decision needs to be made quickly, and in conditions of major uncertainty. It is a typical case of rational choice subject to restrictions (in terms of both time and information). However, it is also an example of a situation where substantive rationality may fall short (Elster 1990, 34). The doctor needs to carry out the optimal number of tests: neither too few, so they are unable to make a diagnosis, nor so many that the patient risks dying before all the tests are completed. Not only will the decision on testing be subject to a cost/benefit analysis; so, too, will the amount of information needed. According to the optimising rationality model, there can be only one optimal decision. Simon takes issue with this decision-making model, pointing out that substantive rationality falls down when confronted with limited computational capacity and attention span, and where uncertainty cannot be further reduced (Simon 1995, 247). Uncertainty derives from a range of factors. Firstly, in the general

sphere of diagnostic tests, uncertainty stems from the lack of *sensitivity* and *specificity* of the tests, with the potential for false positives or false negatives. In terms of limited computational capacity, according to Gigerenzer, another reason why doctors may sometimes not do what is best for their patients is because many of them do not understand health statistics when presented as a Bayesian rule (2014, Chapter 9). In addition, other failings of rationality – cognitive bias or cognitive illusion – have been being reported since records began (Tversky and Kahneman 1979). Doctors themselves attribute such errors not to computational limitations, but to factors such as: limited knowledge and training; fatigue/sleep deprivation as a result of long working hours and shift work; the balance between risk acceptance and risk aversion; and distractions or the handling of the team's resources.[5]

Bearing in mind that doctors, like all other humans, are subject to bounded rationality, we can expect to see one type of designs devised by science. On the other hand, if we employ an «Olympian» model of rationality, we would expect rather different designs to emerge: «To design is to gather information about what follows from what one has proposed or assumed. It is of interest only to creatures of limited information and limited computer power- creatures of bounded rationality like ourselves» (Simon 2007, 151).

Thus, taking account of such bounded rationality, and of the guiding principle behind medicine (to bring about a positive effect in the patients), medicine as a science of design provides elements to improve the art of medicine. The output from that science would be expressed in technical norms of the type: «If you want to heal a patient with these symptoms, you should use this treatment» (Niiniluoto 1993, 12).

Hence, there are parts of medicine[6] which can be described as sciences of design[7]: those parts in which strategies are developed, producing prescriptive rules aimed at improving clinical judgement, or –which is tantamount–

5. The list is drawn from the MSD https://www.msdmanuals.com/professional/special-subjects/clinical-decision-making/cognitive-errors-in-clinical-decision-making (consulted on 7/07/2020), which distinguishes the following cognitive errors: availability error, representation error, premature closure, anchoring errors, confirmation bias, attribution errors and affective error.
6. One example of design in medical practice can be seen in a hospital complex. However, a hospital system can also be understood as a sociotechnical system, as envisaged by Franssen & Kroes (2009, 223): «hybrid systems, consisting of, or involving, «components» or «elements» that […] belong to other domains than just the domain of the material objects described by natural science».
7. The word «design» has a dual meaning. We must differentiate between a design as a plan and a design as a product (González 2007, 3).

making medical practice more efficient. Looking at the example given by Gigerenzer (2005, 4 *et seq*.), science of design provides knowledge to develop rules which enable us to efficiently treat a patient presenting in the emergency room with chest pains. The concrete implementation of this rule would be an HDPI (*Heart Disease Predictive Instrument*) –a pocket-size plastic chart, showing seven symptoms of heart disease along with their respective probabilities–. The HDPI can be used to obtain a point score, through logistic regression, indicating the likelihood that the patient is suffering from acute ischemic heart disease. The symptoms include: chest/left arm discomfort, a history of heart disease, shape of an ECG wave, etc. An alternative design, which Gigerenzer champions, is a heuristic which, using a sequence of three questions, serves as a rule to decide whether to send the patient to the coronary unit or to a bed for observation. The design of such «products» necessarily entails certain objectives – i.e. certain criteria and restrictions. In the example at hand, the criterion might be that there be no false negatives and that the number of false positives not overwhelm the cardiac unit, with the possible adverse consequences for patients» health and healthcare costs. In addition, the design must allow for rapid decision-making, but without endangering the patient's life by causing doctors to act precipitously and without evidence. In fact, Gigerenzer himself speaks of design when referring to heuristics: «The goal is to use the results of the study of the adaptive tool box and ecological rationality to *design* heuristics and/or environments for improving decision making in applied fields such as health care, law, and management» (Gigerenzer 2008, 8) (our emphasis).

The concept of procedural rationality, or satisficing[8] rationality, reflects the process of individual choice by a doctor in the field, exercising clinical judgement, and of *techné* as encountered in the field of design. However, Simon's notion of rationality is limited to a consideration of «means» and «ends». We agree with Wenceslao J. González (1997 and 2008) as to the need for evaluative rationality. As González states in his critique of Simon in relation to economics (an argument which applies readily to medicine): «Evaluative rationality has a key role for scientific design, since the sciences of the artificial are goal oriented, and we need an evaluation on the inherent

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8. Satisficing rationality stands in contrast to optimising rationality. With optimisation, the postulate is that the subject will choose the best alternative within the set of available choices. With satisficing, the subject halts the decision-making process once they have obtained a sufficiently good alternative. In Simon's own words, the term «satisficing» applies to «decision methods that look for good or satisfactory solutions instead of optimal ones» (Simon 1996, 119).

appropriateness of goals» (González 2008, 176). It is important to point out that, although instrumental rationality provides the most appropriate means to achieve a given end, those ends themselves may be inappropriate (González 1997, 213). In actual fact, in medicine, there is no single goal: medicine may have multiple –and, on occasion, mutually contradictory– goals: human life cannot simply be preserved through «therapeutic cruelty» (preserving life for the sake of it, and so prolonging a patient's suffering). Precise diagnostics may be of no use in the case of incurable diseases, life may be unbearable in certain circumstances, etc. The decisions which must be made depend not only on criteria of instrumental rationality, but also on evaluative elements, which may clash with one another.

6. Prediction, prescription and evaluation

Prediction, prescription and evaluation are intertwined in a rather peculiar way in all sciences of design –not only in medicine–. The main objective of sciences of design is to devise strategies to alter reality. To do so, they must be able to envisage a range of possible future scenarios; yet it is equally important to make use of evaluative tools that indicate which of these scenarios is preferable. Plainly, as indicated above, these evaluative tools depend upon the social and cultural context, and in the specific case of medicine, may even depend on the particular circumstances surrounding the human operators (both doctors and patients). That part of medicine which can be described as science of design requires its practitioners to predict various future scenarios, anticipate which treatment is likely to have the desired effect in order to intervene efficiently in the field, and change a present situation into a different one (deemed preferable). The prescriptive rules produced by sciences of design will always be filled with evaluative elements. Therefore, on the basis of those evaluative elements, different designs to achieve similar purposes may differ widely. In the case of medicine, for example, a design whose the overriding aim is to preserve a patient's life might be seen, by others, as opening the door to therapeutic cruelty. On the other hand, these designs have to be implemented within healthcare models which, whether financed publicly or privately, must take account of the financial costs they entail.

Consider the situation that we, experienced in 2020. In the face of the COVID-19 pandemic, different countries have developed differing strategies, reflecting a very diverse range of evaluative elements. The factors upon which these designs were based were not the same. For instance, the starting position differs from one country to another, be it for reasons of the

resources available to healthcare staff or the technology available within the various health systems. However, factors relating to customs, and to social and cultural mores, have also come into play. It must also be borne in mind that in certain cases, other factors were taken into account, such as economic considerations and the consequences that a medical design (lockdown) could have for the country's economy.

Yet this is not something which is unique to medicine as a science of design. In fact, it could equally be applied to any other science of design: while the ultimate objective in all these fields is for their designs to change the world, those designs will be constrained by economic, temporal and material limitations and, of course, by our own bounded rationality, and by the various evaluative systems concerning what is preferable.

7. CONCLUSIONS

Although Simon (1996) explicitly contemplates medicine as a design science, on an equal footing with economics, architecture or engineering, his proposal has not been developed beyond the brief characterization made by Niiniluoto (1993) and briefly discussed here. Throughout the preceding pages we have shown that the characterization of medicine fits better with the features of the design sciences than with those of the social or natural sciences. Just the fact that the goal of research in the design sciences is to improve human skills in that domain would be a good indication that medicine is such a science. However, we think that there are many other aspects of the discipline as a whole that can be characterized through the elements present in the design sciences, beyond what Niiniluoto points out.

As mentioned in the introduction, the first of these features has been the process of scientization and mechanization of medicine understood as an art in its historical development. The second has to do with the type of problems faced by medicine, conceptualized as wicked problems, and the context of uncertainty and urgency in which decisions have to be made. This leads us to a model of rationality specific to the design sciences: bounded rationality. The third is the essential and characteristic role of values in medical practice, values that are different from the epistemic values prevailing in the natural sciences. Here we must emphasize the evaluative component of rationality and depart from Simon's characterization of bounded rationality as an instrumental rationality, in which ends are not evaluated. In medicine, perhaps more than in any of the other sciences characterized as sciences of design, evaluative rationality is fundamental, given that the end of preserving life

proper to the Hippocratic oath sometimes comes into contradiction with the oath itself when there is, for example, therapeutic obstinacy. We must also add the prescriptive component, typical of the design sciences, and fundamental in medical practice, which is linked to this same evaluative rationality and to the fundamental normative component in medicine.

All this leads us to consider that the medicine, in its epistemic aspect, must be characterised in a way that takes account of the complex nature of its objective, which cannot simply be boiled down to the desire to «heal». Behind any medical action lies the need to take decisions effectively in the absence of certainty. Therefore, one strategy to understand medicine would be to view it as a science of design, integrating aspects of bounded rationality, prescriptive and evaluative elements.

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