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Abstract

When we talk about reasoning, we often imagine something purely logical: rigorous deductions, exact calculations, mathematical proofs. But from a cognitive perspective, reasoning is, first and foremost, an activity of the human mind: a set of processes through which we interpret information, make decisions, and solve problems.

Before even studying it in detail, a preliminary question arises. We can look at reasoning in two different ways. We can study it as an actual mental process, trying to understand how people actually reason, with their limitations, strategies, and errors. Or we can construct a normative model, that is, a set of rules describing how one *should* reason.

This second approach has a very ancient history. Aristotle developed a formal system—syllogistic logic—that establishes precise conditions for the validity of inferences. In the centuries that followed, the logical tradition produced increasingly abstract and rigorous systems, often organized in axiomatic form. These systems do not directly describe the functioning of the mind; rather, they provide ideal models against which actual reasoning can be compared.

The cognitive perspective operates precisely in the space between these two poles: on the one hand, the analysis of logical correctness, on the other, the empirical investigation of how people actually think. A major part of today's experimental economics is dedicated precisely to the comparison between formal models and experimental data, attempting to understand under what conditions people fail to reason in the coherent way that logic presumes, and why this happens.

But the reverse process also applies: advances in understanding reasoning give rise to the construction of new models - models that redefine rationality and models that simulate reasoning. In the mid-twentieth century, Alan Turing showed that many mental operations can be described as manipulations of symbols according to precise rules, and therefore that one could attempt to build machines that simulate reasoning as *symbolic computation*. Much of the history of artificial intelligence is based on this idea, leading to the construction of machines that imitate reasoning (the Turing Machine,[1] the forerunner of the computer) or attempts to simulate the functioning of the brain's neural networks.[2]

What is reasoning? According to Aristotle, reasoning is the mental process that, starting from certain premises, leads to a conclusion, using logical procedures called inferences.

Reasoning is not just an abstract exercise in coherence. In everyday life, it is closely linked to the decisions we make and the rules that guide social cooperation. When we evaluate an argument, choose between alternatives, or justify a choice, we are not simply applying logical schemes: we are also interpreting situations, considering consequences, and recalling shared values and norms. In this sense, reasoning is a bridge between the mind and society. On the one hand, reasoning is an individual cognitive process; on the other, it is a tool through which we make our decisions public and debatable, as happens when we engage in a controversy. Logical rules provide criteria for coherence; social norms provide criteria for acceptability and responsibility. Understanding reasoning therefore means understanding how these different dimensions—logical, psychological, and social—intertwine in the concrete experience of thinking and acting.

[1] Turing (1936).

[2] McCulloch e Pitts (1943).

1. Studies on Reasoning

In the academic tradition, reasoning is studied in different disciplines:

1. Philosophy generally studies the factors that qualify reasoning (with respect to its soundness, coherence, appropriateness, and effectiveness), evaluating its structural form and methodological variety.

2. Psychology and cognitive science tend to focus on the psychology of reasoning; the main questions are: how do we reason? What cognitive and neural processes are involved? What role do cultural factors play in reasoning?

Reasoning shares some characteristics with language: every adult knows how to use reasoning, and uses it to argue with others. As with language, the question arises as to whether reasoning is a natural human ability, a genetically inherited mental skill, or whether it is learned. We will briefly discuss this at the end of this paper.

3. Logic, on the other hand, delves into the formal aspect of reasoning, which is represented with a symbolic system whose elements are connected by operations: logic originates from the thought of Aristotle, who constructed it as a formal system, that is, with the same characteristics as the mathematics or geometry learned in schools. Through logic, reasoning is expressed as a calculation, just as through mathematics and geometry we can calculate, for example, the dimensions of a solid.

These dimensions are intertwined for an intrinsic reason that Alan Turing explained simply: if we can understand how a human being reasons, we can symbolically represent its functioning and verify its coherence.[3]

Since reasoning can be represented through formulas, we can attempt to build a machine that performs reasoning, just as we know how to build a machine to perform mathematical calculations.

2. Logic and the Axiomatic Construction of Knowledge

Logic was founded by Aristotle and discussed in a series of writings collected under the collective title Organon around 300 BC. To assess whether a proposition is true, one must determine whether it is based on true premises. The premises are called axioms, and from them one arrives at the necessary conclusions through a syllogism.

A syllogism (from the Greek: συλλογισμός, syllogismos, "conclusion, inference") is a type of logical argument that applies deductive reasoning to reach a conclusion based on two or more propositions asserted or believed to be true. The traditional example is the following:

Premises (Axioms): 1) All men are mortal; 2) Aristotle is a man; Conclusion: 3) Aristotle is mortal.

[3] The main types of reasoning are induction, deduction, abduction, and argument by contradiction. We will primarily consider deduction.

Ordinary everyday reasoning is less elementary than the one just described: it can be difficult and easily lead to errors; for example, given the premises

1) No millionaire is a hard worker 2) Some rich people are hard workers, what is the conclusion? No millionaire is a rich person? [4]

Until modern times, the use of syllogisms was the fundamental method for approaching reasoning. The extraordinary success of Aristotle's works on logic led to the birth of an intellectual project that spanned the entire history of the West: organizing knowledge in a logically coherent manner, through axiomatic structures so as to reliably assess the truth or falsity of every scientific assertion based on premises deemed certain.

Thus, over the centuries, we see not only formal developments in Aristotelian logic, but also the axiomatization of mathematics (Euclid), of the Christian religion (Aquinas), of probability theory (Laplace), and finally of the theory of decision-making (von Neumann).

Axiomatization allows us to resolve conflicts between opposing positions through logical calculation, mechanically and reliably identifying the truth of a proposition based on premises believed to be true. In disputes, this means resolving a dispute with certainty, starting from shared premises and determining which of two opposing propositions the disputants held was the true one.

3. The Extension of the Axiomatic Method

3.1 Mathematics (Euclid)

About a century after Aristotle, Euclid applied the Aristotelian method to geometry. His *Elements* is the first truly axiomatic system in history: starting from five simple postulates (axioms), he deduced the entire geometry of the then-known world. Here, the axiomatic construction reaches its classical perfection.

3.2 Religion: Thomas Aquinas (13th century)

After nearly a millennium, with the revival of Aristotelian studies, Thomas Aquinas made a revolutionary attempt for his time: defining theology as a science. He took from Aristotle the idea that a science is a body of knowledge logically deduced from first principles. He argued that: "If God created rational man, then using Aristotle's logic helps us better understand God." In practice, he suggests logic is the scaffolding that serves to build the palace of faith. Thomas Aquinas adopted Aristotle's logical method to write his masterpiece, the *Summa Theologiae* (around 1265). Aquinas had trained at the Sorbonne (1245–1248) under Albertus Magnus, where he came into direct contact with Aristotle's texts, including *De Sophisticis Elenchis* (the last part of Aristotle's Organon), which were revolutionizing the Parisian method of study by allowing for the identification of logical fallacies. At the Sorbonne he obtained the chair of theology and taught from 1252 to 1259. After a period in Rome, he was recalled to Paris (1268–1272) to deal with an intellectual crisis: the rise of Latin Averroism.[5] Some scholars

[4] The right conclusion is: some rich people are not millionaires.

[5] Averroes, known in medieval Europe as Abū al-Walīd Muhammad ibn ʾAḥmad ibn Rušd (April 14, 1126 – December 10, 1198), was an Arab and Berber philosopher, physician, mathematician, and judge from Muslim Spain. Christians consider

interpreted Aristotle radically (for example, arguing for the uniqueness of the intellect for all men). Thomas Aquinas used the rigor of *De sophisticis elenchis* to demonstrate that the Averroist theses were, technically, "sophisms"—reasonings that seemed true but were logically fallacious.

Based on Aristotle's texts, Thomas Aquinas and the Scholastics transformed logic from a simple classification tool to a critical method for investigating the truth and coherence of scientific/theological discourse. Theology was constructed as an axiomatic system, and fallacies became tools for testing the soundness of every dogma.

Many critical aspects emerge when discussing the axiomatization of theology.

If the axiomatic construction of theology were fully realized, controversies over a religious statement could be resolved by verifying its consistency with the axioms, and debates on the truth of an issue could be limited to considering the truth of the axioms.

However, the idea to confine all truths to an axiomatic system is an illusion, as Gödel has demonstrated, because, as we will see in the next section, in every axiomatic system there are propositions which are true but cannot be proved through axiomatization.

3.3 The Limits of Axiomatization: The Crisis of Leibniz's Dream

In *De Arte Combinatoria* (1666), Leibniz argued that all human reasoning can be transformed into an object of mathematical demonstration, and thus any controversial truth can be resolved through mechanical calculation. The structure of logic should be equivalent to the structure of arithmetic. This insight became, almost two centuries later, an intellectual project.

In the early 1920s, German mathematician David Hilbert (1862–1943) advanced a proposal for the foundation of classical mathematics that has become known as Hilbert's *Program or Entscheidungsproblem*.[6] The program aimed to formalize all of mathematics by placing it in an axiomatic, logically consistent form. Hilbert's program gave rise to a vast field of study over a long period of time. But in 1931, Kurt Gödel demonstrated that in any coherent formal system (powerful enough to describe arithmetic) there exist true propositions that can neither be proved nor disproved within the system itself. Axiomatization, therefore, cannot completely represent all the true propositions of a scientific discipline.

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him, along with his precursor Avicenna, the most influential Muslim philosopher of the Middle Ages. In the West, Averroes became known for his extensive commentaries on Aristotle, many of which were translated into Latin and Hebrew. Translations of his work reawakened Western European interest in Aristotle and Greek thinkers, an area of study that had largely been abandoned after the fall of the Roman Empire. His thoughts generated controversy in Latin Christendom and sparked a philosophical movement called Averroism based on his writings. His thesis on the unity of the intellect, proposing that all humans share the same intellect, became one of the most well-known and controversial Averroist doctrines in the West. His works were condemned by the Catholic Church in 1270 and 1277. Although weakened by the condemnations and criticisms of Thomas Aquinas, Latin Averroism continued to attract followers until the 16th century. (Translation of article in Italian Wikipedia).

[6] See Bodner M. (2025).

Fig.1 Kurt Gödel

Gödel proved incompleteness with two theorems. The first incompleteness theorem states that no consistent system of axioms whose theorems can be listed using an effective procedure (i.e., an algorithm) can prove all the truths relating to the arithmetic of natural numbers. For any such consistent formal system, there will always be statements about the natural numbers that are true but cannot be proved within the system. The second incompleteness theorem, an extension of the first, shows that the system cannot prove its own consistency.

These two works together marked the definitive failure of Hilbert's Program, which hoped to find a solid, complete, and decidable foundation for all mathematics. This result marks the crisis of Leibniz's dream (1666) of being able to translate all reasoning into calculus, although it does not nullify the construction of logic, mathematics, and all other axiomatic systems; it does, however, demonstrate their limitations.

Around the time of Gödel's discoveries and in an attempt to solve the same problem, the first machine to simulate human reasoning was born: the Turing machine, the precursor to the modern computer. In 1936, Alan Turing defined the Turing machine, an abstract device that manipulates symbols on a tape to model any possible "effective procedure" or computation.

The machine was used to address the foundations of mathematics, specifically to solve the *Entscheidungsproblem*, that is, whether there existed an algorithm capable of deciding whether a given statement (in first-order logic) could be derived from the axioms. Turing demonstrated that a machine cannot decide whether an arbitrary formula is provable, establishing that the *Entscheidungsproblem* is unsolvable.

3.4. Logical Errors and Fallacies

As we have seen, in the 12th century, with the rediscovery of the *De Sophisticis Elenchis*, which listed 13 fallacies in logical reasoning, many scholars sought to identify, describe, classify, and analyze fallacious arguments.

According to Hamblin (2022), "A fallacious argument, as almost all accounts from Aristotle onward tell us, is an argument that seems valid but is not."

Given the difficulty of identifying them, fallacies can also be deliberately created by one of the two opponents in a dispute to gain advantage over the other. In fact, a substantial motivation for identifying

and classifying logical fallacies in the Middle Ages was precisely to avoid this eventuality and to ensure fair conduct between the parties involved in a dialectical discussion, that is, a discussion at the outset of which it is unclear where the truth lies.

In medieval universities, logic was not just theory: it was an intellectual combat sport called *Disputatio*. Students and teachers clashed over a thesis (*quaestio*), and the use of fallacies was the "dirty game" that the opponent had to be ready to expose in real time.

With the rebirth of legal studies associated with the University of Bologna (founded in 1088) and the work of Irnerius and the Glossators, Aristotelian logic became the jurist's armor. It was no longer just a matter of knowing the laws, but of knowing how to interpret them and, above all, of winning in court. This is why the uncovering of fallacies was the essential "line of defense" in legal cases.

If in Paris, logic served to explain God, in Bologna, it served to win trials. Roman law (the *Corpus Iuris Civilis*) was a labyrinth of rules. For a Bolognese lawyer, identifying a fallacy in the opposing party's argument meant nullifying evidence or invalidating a charge.

Bologna was the birthplace of the *Quaestiones*, exercises in which students had to defend or attack a legal thesis. Knowing how to unmask fallacies was the only way to avoid being cornered by an opponent.

Law requires that a word have only one meaning. Fallacies *in dictione* (such as ambiguity) were the number one enemy. Bolognese jurists used Aristotelian logic to "clean up" legal language, making contracts and judgments less vulnerable to manipulative interpretations.

In any case, over the centuries, the distinction between the logic and psychology of human reasoning became increasingly pronounced, and in the 17th century Bacon argued that psychological and cultural factors—which he called "idols"—were the source of errors in reasoning, as they generated distortions in human understanding. This view permeated 17th-century philosophy (see Locke, Descartes, Arnauld, and Nicolle, co-authors, for example, of the Logic of Port-Royal), which considered psychology—not logic—the discipline that addressed errors.

A definitive turning point, which can be traced back to Gottlob Frege and dates back to the late 19th century, was the development of anti-psychologism in logic. This approach draws a clear distinction—typical of the prevailing contemporary view—between the roles of logic and psychology: logic should be conceived as the science of judgment, which studies the principles that allow us to evaluate and understand correct, valid reasoning and distinguish it from its opposite. Other disciplines—particularly psychology, but also ethnology and perhaps other types of cultural analysis—are conceived as sciences that study human reasoning processes, that is, people's mental processes, which are not necessarily always coherent. The problem is understanding the origin of fallacies, whether they are systematic or whether, on average, individuals are rational but make logical errors randomly. We will also see that many errors in reasoning are not random but systematic, and some are difficult to correct even among logicians and probability theorists.

4. Rational Decisions in economic theory

4.1 The classical vision of rationality

We have surveyed the adventures of logic as the science of reasoning, beginning with its founder, Aristotle. How are logic and rationality related ?

In the history of thought, logicality has generally referred to the formal correctness of reasoning, whereas rationality has referred more broadly to the capacity to form beliefs, choose ends, select means, and justify action. Logic concerns the validity of inference, not necessarily the truth of the premises or the wisdom of the action.

This is why one can say that logic is "truth-preserving": if the premises are true and the inference is valid, the conclusion must be true. But logic alone does not tell us which premises to adopt, which goals to pursue, or how to act under uncertainty. For this reason, logic is a component of rationality, but not identical with it.

In ancient philosophy, rationality was primarily associated with l*ogos*—the capacity to grasp order, meaning, and truth. For Aristotle, rationality was the defining feature of human beings: to be rational meant to deliberate about ends and means in accordance with virtue and practical wisdom (*phronesis*). Rational action was inseparable from *ethical life*. As we have seen, in medieval scholastic thought, logic was part of the discipline of correct reasoning, but rationality was embedded in a broader theological and metaphysical order. Human reason was understood as the faculty by which human beings could grasp truth, natural law, and divine order, even if imperfectly.

Reason was seen as a God-given faculty allowing humans to understand natural and moral law. Rationality thus retained a normative and teleological character: it was oriented toward truth, goodness, and cosmic order.

With early modern philosophy, especially Descartes, Hobbes, Leibniz, and later the Enlightenment, rationality became more closely associated with clarity, method, calculation, and systematic knowledge. Descartes emphasized clear and distinct ideas; Hobbes treated reasoning as a kind of computation; Leibniz imagined a universal calculus of reason.

Here we see an important historical movement: rationality begins to be increasingly identified with formal method, calculation, and deductive order. The logical and the rational move closer together.

Rationality can help us discover the means, but desires and sentiments provide motivation. This anticipates a major distinction that later became central to economics: instrumental rationality versus substantive rationality.

Kant offers one of the clearest distinctions. Formal logic gives universal rules of valid thought. But reason, for Kant, is broader. It seeks unity, principles, and justification. In practical philosophy, rationality is not merely choosing efficient means; it is the capacity to act according to principles that can be universalized.

This is important because Kantian rationality includes a normative dimension. A rational agent is not simply a calculator of advantage. A rational agent can ask whether a maxim is justifiable as a universal law. Thus rationality includes autonomy, duty, and moral law.

A turning point is represented by Bentham and utilitarianism. Classical practical reason had generally linked rationality to logical consistency, prudence, and some ethical orientation toward the good. Bentham transformed this tradition by translating moral and political evaluation into a *calculus of pleasure and pain*. In its original ethical form, utilitarianism was not a doctrine of selfishness: it aimed at the greatest happiness of the greatest number. Yet its psychological premise – that individuals are moved by the pursuit of pleasure and the avoidance of pain – offered economics a powerful simplification. Rationality could now be interpreted as the consistent calculation of advantages and disadvantages by an individual seeking utility.

In this passage, the ethical dimension of rationality was not immediately denied, but it was transformed into a calculus of consequences. Later economics detached this calculus from Bentham's collective ethical project and converted it into the model of the self-interested utility maximizer. Bentham thus marks a crucial transition from rationality as ethical-practical judgment to rationality as calculative utility-seeking.

In its ethical form, utilitarianism remains universalistic: the right action is the one that maximizes the greatest happiness of the greatest number. But in its psychological and economic reception, Bentham also encouraged a model of the individual as a calculator of pleasures and pains. This fundamental hedonism progressively gave rise to a view of the individual as exhibiting a natural, rational self-interest—a form of psychological egoism.

Some aspects of this position had already been implicitly put forward in the Book of Fallacies (1824), where Bentham writes "in every human breast… self-regarding interest is predominant over social interest; each person's own individual interest over the interests of all other persons taken together." [7]

Rationality could now be interpreted as the consistent calculation of advantages and disadvantages by an individual seeking utility. Bentham thus marks a crucial transition from rationality as ethical-practical judgment to rationality as calculative utility-seeking.

4.2 From Bentham to the contemporary approach to rationality

The major transformation occurs with marginalism and neoclassical economics. Rationality becomes increasingly formalized. The economic agent is represented as choosing the best alternative according to preferences, given constraints.

In this framework, rationality is not identical to logic, but it becomes highly "logical" in structure. A rational agent is expected to have preferences satisfying certain formal properties: completeness, transitivity, consistency, and sometimes continuity and independence. Choice becomes rational when it can be represented as utility maximization.

This is a decisive narrowing of rationality. The economist does not ask whether the ends are morally defensible, socially learned, psychologically realistic, or historically formed. Preferences are taken as

[7] The Book of Fallacies (London: Hunt, 1824, pp. 392-3)

given. Rationality means coherence in the relation between preferences, beliefs, constraints, and choices.

In this perspective, one property attributed to rationality is particularly relevant: selfishness. Selfishness means that every individual pursues his goals disregarding the effects on the other individuals. It is common to observe in the real world selfish behaviors which have negative effects on other persons, or to the social welfare. Standard economics claims that if there is perfect competition, the decisions of selfish buyers and sellers on the markets are reciprocally compatible. Thus selfishness is not socially harmful in economic decisions, under condition of the working of competition, which leads markets to equilibrium.

The metaphor of an "invisible hand" which maintains that , while acting in their own interest, individuals unknowingly contribute to the well-being of society, is attributed to Adam Smith and enjoyed incredible success among economists, as a way to justify "laissez faire" policies.

However, conditions of perfect competition do not always exist, especially in the presence of public goods. Under such conditions individuals can generate negative or positive externalities that are not compensated for by the market; as a result they must negotiate with one another, limiting the goals they could have achieved from a self-interested perspective.

Negotiation therefore presupposes that individuals recognize the reasons of others, a human characteristic that Smith calls "sympathy," a component of "moral sentiments."

Adam Smith recognized both the calculation of self-interest and moral sentiments as the foundations of social order. For him, individuals were not purely "selfish" (self-centered), but capable of empathy (sympathy) and respect for norms.

For Smith, human beings do not judge their own conduct only from the standpoint of private interest. They also imagine how their conduct would appear to an external, fair, and well-informed observer. This imagined observer is the *impartial spectator*.

The impartial spectator is not simply another real person. It is an internalized point of view: a mental standpoint from which we evaluate our passions, desires, and actions as if we were looking at ourselves from outside.

Therefore the individual is not only an interest-seeking actor but also a self-evaluating moral agent. The impartial spectator represents the internalized standpoint of social judgment through which the agent moderates passions, restrains selfishness, and seeks conduct that can be approved as proper and just. This is why there is no simple contradiction between *The Theory of Moral Sentiments* and *The Wealth of Nations*. In *The Wealth of Nations*, Smith analyzes the coordinating role of self-interest in markets. But in *The Theory of Moral Sentiments*, he shows that human conduct is also shaped by sympathy, moral approval, and self-command. Economic life presupposes these moral foundations, especially justice and trust.

In brief: the impartial spectator is Smith's way of explaining how moral judgment becomes internalized within the individual, limiting selfishness and making social cooperation possible.

However, this latter aspect was not incorporated into modern rational decision theory and the notion of rationality, understood as the consistent pursuit of the goals sought by self-interested individuals, dominated the economic theory for two centuries. It was only at the beginning of the present century, especially with the work of Ostrom (1992), that studies on rationality entered into relation with studies on cooperation, and a line of research that studies social behavior and altruism emerged (Fehr and Fishbaker)

4.3. Decisions under Risk

It is very common for decision-making processes to involve unknown factors to which we can at best attribute a certain probability, as happens in risky decisions, where most individuals attempt to protect themselves from potential losses (for example, when we take out insurance to avoid the risk of having to pay for a car accident). It was therefore necessary to incorporate this aspect into the theory of rationality. This occurred very slowly with the convergence of decision-making studies and the evolution of probability theory. Blaise Pascal and Pierre de Fermat (in 1654) began to calculate the risk in gambling, but it was not until the late 1700s that Laplace created a complete theoretical framework for the construction of probability theory. Interestingly, his concern was to provide ordinary citizens with a set of rules to prevent them from ruining themselves through gambling.

The most important step in integrating the two theories began with a famous study: Bernoulli (1738) constructed a model in which individuals' preferences also included risk, and was able to formally explain risk aversion (or propensity).

The definitive formalization of the theory—which has become standard today—is due to von Neumann and Morgenstern (1944) and Kenneth Arrow (1951). In its current form, the theory of rationality under risk is also called Expected Utility Theory.

Herbert Simon (1978) comments in his Nobel Memorial Lecture: "The axiomatization of utility and probability after World War II and the revival of Bayesian statistics paved the way for empirical verification of whether people behave in choice situations in such a way as to maximize subjective expected utility. In early studies, using extremely simple choice situations, it seemed that perhaps this was the case. When even small complications were introduced into the situations, large deviations in behavior from the predictions of the theory quickly became evident. Some of the most dramatic and convincing empirical refutations of the theory were reported by Kahneman and Tversky (1972). Let us now look at the studies and experiments on fallacies in probabilistic decisions.

4.4 Fallacies in Probabilistic Decisions

Even in the realm of risky decisions, such as gambling, players' actual behaviors can deviate from the behaviors predicted by probability theory.

The best-known phenomenon in this regard is today called "the gambler's fallacy". It occurs when the sequence of numbers drawn in repeated lottery draws does not appear random to gamblers. In a random sequence of tosses of a fair coin, for example, gamblers expect sequences in which the ratio of heads and tails in any short segment remains much closer to 0.50/0.50 than probability theory would predict. In other words, gamblers expect even a brief sequence of heads in a coin toss to be balanced by a tendency for the opposite outcome (e.g., tails) and bet accordingly.

The fact that some gamblers' beliefs about probability are *systematically erroneous* becomes increasingly evident as the theory progressed. Since the publication of his "Philosophical Essay on Probabilities" in 1796, Laplace was already concerned about errors of judgment to the point of including a chapter entitled "*Des illusions dans l'estimation des probabilités*". This is where we find the first published description of the gambler's fallacy.

The development of the Probability Theory allowed a parallel advancement from the Utility Theory that we have considered so far to a new version which includes decisions in the context of uncertainty, called Expected Utility Theory (EUT).

As was evident from the gambler's fallacy. Discrepancies between prescriptions of the theory and real behavior were well known from the beginning, but were considered a minor problem because deviation was supposed to be distributed as statistical errors. In 1952, Friedman and Savage published a famous study in which they constructed an expected utility curve that, they argued, provided a reasonably accurate representation of behavior at the aggregate level. In their article, they assumed that deviations from rational decision making could occur, but only randomly distributed. Friedman suggested an evolutionary defense of economic rationality, arguing that those who did not conform to rational behavior would be gradually excluded from the market due to their inefficiency.

The most serious challenge to this belief emerged with the Allais experiments. In 1953, Maurice Allais conducted experiments on individual preferences, showing systematic deviations from theoretical predictions. Since his article, a growing body of evidence has revealed that individuals do not necessarily conform to the predictions of decision-making theory, but rather appear to *systematically* deviate from them.[8]

Many proposals have been put forward, especially since the mid-1970s, all based on attempts to relax or slightly modify the original axioms of the Expected Utility Theory.[9] None of them have been statistically confirmed across the entire scope of applicability.

Therefore, this response to Allais's criticisms proved to be valid. Only gradually did economists recognized the systematic discrepancy between the predictions of the Expected Utility Theory and economic behavior. This paved the way for the development of a new line of research called "experimental economics". It is aimed at testing the validity of economic propositions with respect to the actual behavior of individuals.

5. The Cognitive Foundations of Rational Decision Making

5.1 The Cognitive Basis of Decision Making: The Magic Number Seven

Psychology and cognitive science thus become the lifeline for understanding and describing human decisions and for rethinking the very concept of rationality.

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[8] More precisely, modern Expected Utility Theory is based on four fundamental axioms (plus two auxiliary ones) and, in the more classical Aristotelian tradition, Allais' experiments show that one axiom - the "cancellation" axiom - is systematically violated in actual behavior.

[9] Among others, the *Weighted Utility Theory* (Chew and MacCrimmon), the *Regret Theory* (Loomes and Sugden, 1982) and the *Disappointment Theory*, (Gul, 1991).

Kahneman and Tversky comment: "The logic of choice does not provide an adequate basis for a descriptive theory of decision-making. We argue that deviations of actual behavior from the normative model are too widespread to be ignored, too systematic to be dismissed as random errors, and too fundamental to be accommodated by expanding the normative system. We begin with a brief analysis of the foundations of the Rational Choice Theory, then demonstrate that the theory's most basic rules are commonly violated by decision makers. From these results, we conclude that normative and descriptive analyses cannot be reconciled."[10]

If the logic of choice does not provide an adequate basis for a descriptive theory of the decision-making process, as Kahneman and Tversky argue, the only viable option is experimentation, which highlights the cognitive processes underlying the decision.

George A. Miller, in his famous 1956 article "The Magical Number Seven, Plus or Minus Two," discovered that when we operate on symbols—for example, when performing mathematical operations or discussing a legal proposition—we encounter a very strong memory constraint. On average, individuals can process seven elements simultaneously: if you try, for example, to mentally perform a simple operation like 5781 * 8639, you won't succeed: during the necessary intermediate steps of the operation, you would have to keep more than seven numbers in mind. The same applies to proving a theorem and to reasoning in general. The key point is not the number 7 itself, but the idea that the mind has a structurally limited capacity to process simultaneous information.

Miller's article had a profound impact on theories of cognitive limitations and thus, indirectly, on theories of human reasoning. Although the precise numerical limit remains a matter of debate—subsequent research suggests a capacity closer to four rather than Miller's famous "seven plus or minus two"—the theoretical implication is solid: human reasoning operates under rigid architectural constraints. There is agreement that:

1 Reasoning requires the use of working memory. For example, considering alternative hypotheses in a discussion involves the use of working memory and places a cognitive load on it.

2. When the load exceeds the available capacity of working memory, errors increase. This has been extensively documented in experiments involving logical and probabilistic tasks.

3. The load is reduced when the problem can be represented in a more compact way (chunks, schemas, frames).

This constraint has profound consequences. If working memory is limited, reasoning cannot approach the ideal of unlimited computation hypothesized in classical Rational Choice Theory. Cognition must instead be based on compression, structuring, and selective representation of information. The issue is not simply quantitative (how many elements can be retained simultaneously), but structural: reasoning depends on how information is organized into meaningful units.

[10] Tversky and Kahneman (1986).

5.2 Bounded Rationality

The most important step in rethinking the theory of choice was taken by research conducted since the 1950s by Herbert Simon (and his group at Carnegie Mellon), starting from the observation that only a modest part of our preferences are given in advance and remain stable in our mind. Organizing the basic elements of choice requires complex mental work (certainly not on the modest scale of "magic number seven").

Before making a decision, our mind must therefore engage in the complex process of organizing the problem, representing it, recalling from memory relevant information or searching available external information and forming preferences.

The preliminary activity can therefore be defined "problem solving," and entails selective search conducted across problem spaces.

The typical case is that of chess: there is a winning strategy, but identifying it would require computing power that is still not available even using today's most powerful computers.

The human mind therefore follows "shortcuts" based on empirical rules or "heuristics," in which the player, exploring only a small part of the problem, identifies a strategy that is certainly not optimal, but locally good (and hopefully better than that of the opponent). You win not because you have unlimited computing power, but because of your way of representing the problem is more effective and richer than your opponent's.

The first empirical studies on chess date back to De Groot (1965), who observed that chess masters were able to remember and identify the positions of the pieces on the board after only five seconds of study. He found a clear superiority of the masters over less experienced players in recalling significant information. This ability could not be attributed to a generally superior mnemonic capacity of the masters, since when chess positions were constructed by placing the pieces randomly on the board, the masters were no better at reconstructing them than less experienced players. Therefore, the masters appear to be limited by the same severe short-term memory limitations accumulated over years of consistent practice (Chase and Simon 1973, pp. 55-6).

De Groot attributed the masters' above-average performance to their ability to classify groups of pieces as examples of familiar game categories and thus concluded that the key to their expertise lies not in superior general processing abilities, but rather in domain-specific skills. These abilities provide masters with a rapid and unconscious perceptual ability to process game configurations.

“A key to understanding chess mastery…seems to lie in immediate perceptual processing, since it is here that the game is structured and it is here, in static analysis, that the right moves for subsequent processing are generated. Behind this perceptual analysis, as with all skills… lies a vast cognitive apparatus accumulated over years of consistent practice. What was once accomplished through slow, conscious deductive reasoning is now achieved through fast, unconscious perceptual processing. It is not a linguistic error when the chess master says he “sees” the right move” (Chase and Simon, 1973, p. 56).

This characteristic—the fact that when we successfully solve a frequently occurring problem, we memorize the solutions and reuse them in reasoning automatically and partially unconsciously—is

essential to understanding how the mental process of problem-solving occurs. Simon calls "chunking" the process by which we aggregate and connect mental items so that they can be used in reasoning. Individuals group individual pieces of information (such as letters, numbers, or concepts) into familiar, structured wholes to make them easier to remember.

An expert chess player does not see 32 individual pieces on a board. He recognizes familiar clusters of pieces, such as a "weak castled king position" or a "pawn chain." A grandmaster has memorized up to 50,000 of these chess chunks.

While looking for a good move or a good local strategy that involves multiple moves, the player simplifies the search by using heuristic rules. *Heuristics* are mental shortcuts or "rules of thumb" that the brain uses to simplify the search and make decisions quickly. Instead of calculating millions of future moves algorithmically, the player's brain recognizes a chunk and instantly applies a heuristic shortcut: *"When the opponent's castled king position is weak, launch an immediate kingside pawn storm."*

Then: a chunk is a meaningful unit of information stored in long-term memory, while a heuristic is the mental shortcut that uses those units to make quick decisions. Together, they allow the human brain to bypass slow, deliberate processing and solve complex problems instantly.

The concept of chunking, already implicit in Miller's work, provides a bridge between cognitive limitation and structured reasoning. A chunk is not a simple aggregation of elements, but a meaningful unit formed through previous learning and experience. Chunking reduces cognitive load by reorganizing dispersed information into higher-order structures.

Experimental data on puzzle solving, for example, show that most individuals, once they have identified a strategy and used it repeatedly until it becomes familiar, tend to stick with it even in novel contexts where better strategies would be available (Luchins 1942) .

Neurological data also show that skill-specific training makes performing a task easier, as in the case of playing Tetris:

The blood flow to the brain of a novice (left) compared to an expert (right) while playing Tetris shows that the expert exerts significantly less effort to complete the same task.

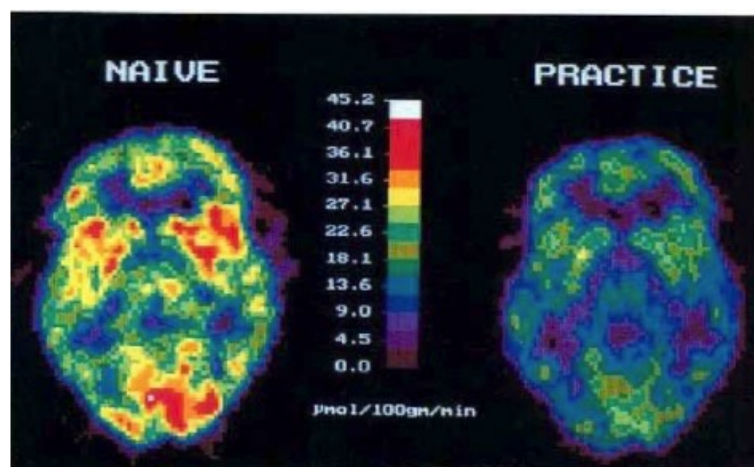

Fig. 2 Oxygenation level in the Tetris game

Experiments demonstrate that, once a mental calculation deliberately performed to solve a given problem has been applied repeatedly to solve similar problems, it can become "routine." Routinization allows individuals to move from deliberate and effortful mental activity to partially automatic, partially unconscious, and effortless mental operations.

5.3 The Dual System of Reasoning and the modern fallacies to rationality

Luchins' experiments fully correspond to the distinction between controlled and automatic processes: they show how a controlled reasoning process—typically composed of slow, serial, and effortful mental operations—is replaced by an effortless automatic thought process.

This result has given rise to a dual model of problem-solving, according to which thinking occurs through two different cognitive processes: on the one hand, a controlled, deliberate, sequential, and effortful calculation process; on the other, a non-deliberate, automatic, effortless, parallel, and fast process. The two processes have been described in many different ways by different authors, but today there is a broad consensus among psychologists on the characteristics that distinguish them.

The distinction was raised by Posner and Synder (1975) when they asked what level of conscious control individuals have over their judgments and decisions. Among other authors who have addressed this issue, Schneider and Shiffrin (1977) defined the two processes as "automatic" and "controlled," respectively.

According to Schneider and Shiffrin, automatic processing is the activation of a learned sequence of elements stored in long-term memory. This sequence is initiated by appropriate input and then proceeds automatically without the subject's control, without pushing the system's capacity limits, and without necessarily requiring attention. Sequences may be the result of perfectly rational reasoning, such as rational strategies for solving simple problems. Their storage in long-term memory leads to automatic retrieval and use in contexts that are not necessarily identical to the situations in which they originated.

Precisely because the use of memorized structures (chunks) in reasoning occurs in an uncontrollable and unconscious way, individuals can use them in contexts that do not correspond to the original problem, thus making reasoning errors: this is the intuition of Kahneman, which has given rise to intense research and has influenced the current development of behavioral economics. The two processes, the automatic recall of known solutions from long-term memory and reasoning as calculation, are represented in Kahneman's Nobel Lecture as "intuition" and "reasoning," as in the following table.

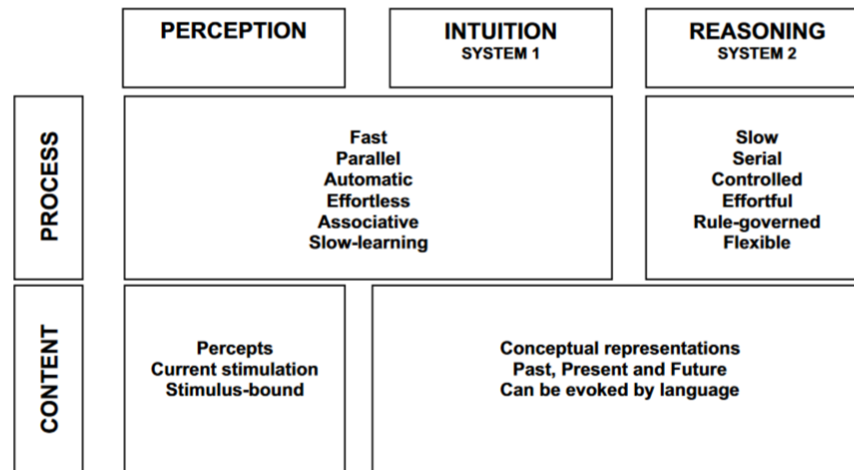

Fig. 3 From Daniel Kahneman's Nobel lecture

As Kahneman and Tverky neatly remark, the discrepancy between actual behaviors and those predicted by the Expected Utility Theory model is consistent across many different contexts. The problem, therefore, is whether this occurs as a result of some cognitive mechanism and whether it is possible to correct these *fallacies*.

To respond to this question it is useful to recall the concept of Heuristics and underline the dual role they cover in the process of reasoning.

On the one hand, while they save time and cognitive energy during the mental work required to achieve the solution of a problem, heuristics can sometimes lead to predictable errors in judgment, known as *cognitive biases*.

Consider the first characteristic. Biases are viewed as cognitive deviations from logically consistent behavior and have been classified as anomalies respect to the Expected Utility Theory predictions. Under this view, heuristics are useful shortcuts, but they often generate predictable mistakes. A major line of research has focused on the study of biases, which have been classified under many different typologies. The central question is to explain what are the mental processes which give rise to the different kind of biases, and so far the solution to this question is largely incomplete. In this context, therefore, bounded rationality refers primarily to the systematic limitations of human judgment.

5.4 The Dual System of Reasoning and the modern fallacies to rationality

According to the dual model account of reasoning, biases are originated during the "dialogue" between intuition and reasoning. As the studies of chess grandmasters show, the decision process , accomplished through slow, conscious reasoning, is guided and simplified by a fast, unconscious perceptual processing that incorporates heuristic rules. Heuristics have been considered as shortcuts, simplifications of the rational procedure, which originate biases. On the other hand, heuristics outperform the rational procedure in situations involving computational complexity, data missingness,

or strict time constraints. In these environments, finding the rational procedure is either impossible or inefficient because too slow.

Note that for every unfamiliar situation, preferences, expectations, and strategies have not yet been established, so the problem is their construction.

In these conditions, search is necessary and heuristics are a necessary component of induction.

Thus a different interpretation of the role of heuristics can be considered, as a constitutive part of the construction of the solution of a problem. This view has been provided by Gigerenzer: bounded rationality reveals not primarily human error, but the adaptive intelligence of simple heuristics. He argues that heuristics are not inferior substitutes for optimal calculation; in many real environments they are precisely what makes good judgment possible.

Kahneman's approach is closer to behavioral economics: human beings are predictably irrational because their intuitive judgments often violate formal rationality.

Gigerenzer's approach is closer to evolutionary and ecological rationality: human beings rely on fast and frugal heuristics that have evolved, culturally and biologically, because they work well in recurrent environments.

It is curious that an important point in support of Gigerenzer's perspective comes from an observation by Kahneman himself:

"The individuals we examine do not pass the extremely difficult tests of logical rationality; they do not possess a coherent system of beliefs or a complete set of preferences. For the most part, they calculate their beliefs and preferences on the spot, and their calculations are susceptible to systematic biases and the arbitrary effects of context. On the whole, however, limitedly rational individuals are reasonable, if not perfectly rational. In other words, there is no contradiction between the picture painted by cognitive psychology and the sense of wonder that arises when faced with the extraordinary capabilities of the human mind."[11]

This remark changes radically the perspective of behavioral approach, which is limited to the idea that human beings are predictably irrational because their intuitive judgments often violate formal rationality. The question is different: while people may be temporarily irrational, everyone has the ability to move beyond irrationality because everyone is capable of learning.

The problem of the role of fallacies must be expanded to incorporate the issue of the mental mechanisms that enable learning. In fact, there is no reason to expect that reasoning perfectly reflects the formal model of logic. Logic is a human construct, and the true miracle is that a single individual can rediscover it through a mental process of learning and discovery.

More importantly in the case of rationality in economics, the traditional notion of the rational individual as pursuing with consistency and selfishness his interests cannot be considered as an abstract universal

[11] Speech delivered by Daniel Kahnemann on the occasion of the awarding of an honorary doctorate at Trento University (14/10/ 2002). Unpublished paper.

property; this is because neither full consistency over the entire set of preferences can ever be reached, nor selfishness guarantees the best (individually or socially) behavior.

A person may act rationally by respecting a rule because the rule sustains trust, cooperation, legitimacy, or social order, and limiting the pursuit of his strict egoistic interest.

Here logic alone is insufficient. One can logically derive free riding from selfish premises in a public goods game. But if the premises are too narrow, the conclusion may misrepresent actual rationality. The issue is not whether the deduction is valid, but whether the model captures the relevant motives, norms, and institutional context.

This suggests again that individuals are not merely selfish calculators. They often take into account the harmful external effects of their actions on others, especially when norms have been socially learned and internalized. Such behavior may not be "logical" in the narrow maximization sense, but it may be rational in an evolutionary, institutional, and normative sense.

In this regard, Gigerenzer's view deserves attention because it supports the idea that institutions and norms may themselves be repositories of adaptive heuristics: they guide behavior not by replacing rationality, but by making bounded rationality socially effective.

6. Final Considerations. Open Problems

Let me return to the question I have outlined in the introduction: to what extent is reasoning a natural human capacity, a genetically inherited mental skill, and to what extent does it depend on social factors? An interesting answer is provided by Jean Piaget's (1962) studies on how children develop the ability to think logically and scientifically. According to Piaget, intelligence evolves through the progressive construction of operational structures starting in early childhood. His theory outlines four stages of cognitive development: sensorimotor, preoperational, concrete operational, and formal operational. Through this process, kids move from basic reflexes to complex reasoning.

This point is relevant because it clarifies that logic ability is a skill acquired over time and during mental development. Piaget extends his analysis to the moral domain. His theory of moral development explains how children's understanding of rules, fairness, and justice evolves. He proposed that moral reasoning transitions from a rigid obedience to external authority (rules are absolute) to a flexible, internalized morality based on cooperation, mutual respect, and context (intentions matter) .

His view lead us to a profound question: Are moral rules innate, in the meaning of Kantian philosophy? Or are they constructed constraints imposed externally (heteronomous morality) on children, which are then internalized and reconstructed as principles of reciprocity and fairness (autonomous morality) through interaction, cooperation, and perspective-taking?

In Piaget's view, moral reasoning emerges neither as innate content nor as mere social imitation, but as a constructed coordination of perspectives under cognitive constraints. I suggest that readers of this paper compare these views with their own convictions about the origin of morality. Moreover, we may wonder how our cognitive structures, through which we reason and interact with others, are formed;

what effect the social norms and values we learn have on us; and what the limits of our independent thought and reasoning are.

Contemporary research is providing us with new tools to understand how we form our opinions and how we organize our thoughts to make decisions. These are very significant advances in making us aware of our choices.

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