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Article

From Rationality to Scientific Rationality: Conceptual Indeterminacy and Methodological Delimitation

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Abstract:

This article argues that the concept of rationality, widely used across disciplines, suffers from conceptual indeterminacy, obscuring its precise definition and boundaries. This necessitates a clear and coherent definition to delimit its scope and to grasp the specific relationship it maintains with science. Rationality holds particular epistemological value within the scientific domain, where it is closely tied to the scientific method. We explore how the general notion of rationality has evolved into the more specific concept of scientific rationality and examine how it diverges from other forms of rational thought. Our central hypothesis is that "rationality" lacks a straightforward definition, even in scientific contexts, and is instead understood through stipulative definitions due to its inherent complexity and broad lexical field. This inquiry aims to clarify the methodological and conceptual delimitation of scientific rationality.

Keywords: Conceptual indeterminacy; Logical analysis; Methodological analysis; Rationality; Scientific rationality

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Introduction[2]

The concept of rationality is commonly associated with scientific pursuits, particularly given the esteem in which such activities are held in modem times (Gottschalk and Witkin 1991, 122-123). However, it is important to recognise that this term is used in a broader context, extending beyond the scientific domain and entering everyday language. The pervasive usage of the term "rationality" has resulted in a situation where some individuals refrain from offering a definition of rationality, even in instances where it is deemed essential, instead

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[2] This paper is an edited chapter from my thesis (PhD). Quotations made in this work from books or articles written in French are my translations.

operating under the assumption that it is self-evident (Dupuy and Livet 1997).[3] Conversely, there are those, exemplified by the work of Stanovich, West and Toplak (2016), who acknowledge the inherent challenges associated with defining rationality.

> "Rationality" is a torturous and tortured term in intellectual discourse. It is contentious and has a multitude of definitions. The term is claimed by many disciplines and parsed slightly differently by each discipline. Philosophy, economics, decision theory, psychology – all claim the term and have their own definitions. […] Across disciplines, scholars agree on only one thing: there are many definitions of rationality and they differ across scholarly domains. (Stanovich, West, and Toplak 2016, 3)

The nuances of its meaning are shaped not only by formal definitions within specific disciplines but also by its flexible application in everyday discourse. This multifaceted nature of rationality makes it challenging to arrive at a singular, universally accepted definition. It is perhaps no coincidence that its use in ordinary speech, as well as in some scientific writings, is often accompanied by an absence of clear definition.

Rationality is tightly bound up with the notion of reason, and, paradoxically, in addition to the difficulties of defining it, it is not the most universally recognised characteristic of science. While it has been championed by figures like Kant (1998), Lakatos (1989) and Popper (2005a), it has also faced critiques from scholars such as Feyerabend (1993), Horkheimer (2004) and Marcuse (1964). This article takes this standpoint and sets out the hypothesis that rationality does not admit of a single, non-problematic definition, even within scientific contexts. Rather, what is commonly referred to as "scientific rationality" emerges through a series of stipulative and methodological constraints imposed on a broader and more elusive notion of rationality. According to this perspective, scientific rationality does not resolve the indeterminacy of rationality as such; it narrows and disciplines it.

Toward this end, the paper proceeds in three stages. The next section adopts an etymological approach to illuminate the semantic roots and transformations of the concept of rationality. The following section offers an epistemological analysis of competing attempts to ground scientific rationality, with particular attention to debates over verification, falsification, and critique. The final section examines logical analysis as a central methodological instrument in the construction of scientific rationality, assessing both its historical role and its philosophical limits.

Etymological Approach to the Concept of "Rationality"

The term "etymology" denotes the study of a word's historical formation with a view to discerning its primary meaning while also examining its subsequent evolution with a view to achieving a detailed understanding of its current meaning. More importantly, understanding a word's etymology is often decisive for its interpretation. As noted by Barney *et al.* (2006, 55), "The knowledge of a word's etymology often has an indispensable usefulness for interpreting the word, for when you have seen whence a word has originated, you understand its force more quickly. Indeed, one's insight into anything is clearer when its etymology is known".

To put this in a different way, the etymological approach, as a tool for interpreting words, provides an *effective* and *reliable* insight into "the variety of meanings – past and

[3] In this collective book, everything is done as if the idea of *rationality* were a matter of common self-evidence, and the authors, no doubt deluded by their own familiarity with the word, have not bothered to specify its meaning to any great extent. To illustrate this further, a third of the papers in this book use the word "rationality" in their title, without any explicit definition being given in the text.

present – attached to a range of terms that played a pivotal role in discussions of culture, [*science*] and society, and of the relations between them" (Bennett, Grossberg, and Morris 2005, 16).[4] To complete the picture, it is important to note that the etymological approach often requires an examination of a term's root in ancient languages such as Latin and Greek. Through subsequent analysis and interpretation, this method provides insight not only into the word's contemporary meaning but also into the nuances that have shaped its evolution over time and influenced its application within various domains of knowledge.

If, by this one means the etymological study of a term, the recent volume *The handbook of rationality*, edited by Markus Knauff and Wolfgang Spohn (2021), while offering a thorough historical approach in its Section 1, "Origins of rationality", does not fully address what a comprehensive etymological study of rationality would entail. Notably, the term "etymology" is mentioned only twice (on pages 51 and 71) in this extensive 879-page work. This observation highlights the need for a more systematic etymological exploration of the concept of "rationality", which is the approach we aim to undertake in this section. This is not to suggest that the historical approach offers no insight into understanding the nature of rationality. On the contrary, its contribution is far from negligible. To underscore the significance of this approach, one can reference Thomas Nickles' compelling article (2021), which presents, among other relevant points, fourteen thought-provoking questions derived from the analysis of historicist conceptions of rationality. These questions provide valuable insights, some of which will undoubtedly inform the subsequent analysis. Notably, question 4 (*Is there just one, unique, correct conception or theory of rationality, of universal applicability?*) and question 6 (*Is scientific rationality special in some way, as distinct from rationality in general?*) are particularly relevant to the discussion. As we pursue this etymological approach in its distinctiveness, two key features should be emphasised as guiding principles. First, "etymology (*etymologia*) is the origin of words, when the force of a verb or a noun is inferred through interpretation" (Barney et al. 2006, 54). Second, "The etymologies of words are derived from a variety of sources [...], including Latin and Greek" (Barney et al. 2006, 55).

On this note, the term "rationality" shares its Latin root, *ratio*, with the word "reason", which translates into French as calculation, order, or organisation. Grounded in this origin, *ratio* links the concept of rationality strongly to logic, which serves as both a mathematical discipline (ratio as calculation) and a philosophical one (the demand for meaning, where *ratio* represents the organisation of thought). Before proceeding with further interpretation, it is important, as David Hoffmann (2003, 27) reminds us, to recognise that the unquestioned identification of *logos* with *ratio* (reason) marks a significant shift in the development of Western thought, moving away from its Greek origins. Thus, this interpretative stance was influenced by later traditions centred on rationality and demonstrative reasoning.

On closer scrutiny, this perspicacious observation regarding the etymological interpretation of the word "ratio" – largely overlooked despite its significance – constitutes a noteworthy contribution to the field. If it were to receive the attention it merits, this could have a significant impact on a number of existing lines of enquiry. Anyway, we contend, in accordance with our pursuit, that the previous interpretation remains valid, and we endorse, consequently, the view that rationality can be understood as a kind of determination, whether theoretical or practical. "Determination", here, implies that rationality is not just a passive attribute but an active force that shapes both theoretical constructs within the scientific domain (influencing the formulation of hypotheses, methodologies, and interpretations of data) and practical applications, actions and decisions in real-world scenarios.

[4] We have slightly adapted the quotation to fit our context.

In this framework, thought is constrained by strict rules that guarantee either the *soundness* of conclusions within the domain of *knowledge* or the *consistency* of actions with reason within the sphere of *practice*[5]. Implicitly, the defence of rationality suggests that "Scientific knowledge, and the human rationality that produces it, are, [...] always fallible, or subject to error" (K. R. Popper 1995, 8). However, this inherent flaw can be mitigated through the imposition of certain constraints. Therefore, anything bearing the hallmark of rationality, when subjected to rigorous rules, can be both explained and justified, thereby claiming a scientific or objective standing.

The relationship thus established between rationality, scientificity, and objectivity, which stems from the Latin term *ratio* (reason), becomes even clearer when examining the Greek term *logos* (*λόγος*). While *logos* is regarded as "the original root of the modern English word 'reason'" (Yang and Xiong 2016, 2), it encompasses "such a broad range of meanings and varied uses that it is difficult to grasp, from any other language, as anything other than plurivocal, and in any case, it is impossible to translate it except through a plurality of distinct words" (Cassin 2004, 747). Literally speaking, the term *logos* is closely associated with various concepts, including "speech, language, tongue, word, rationality, reason, intelligence, foundation, principle, motive, proportion, calculation, ratio, relation, narrative, thesis, reasoning, argument, explanation, statement, proposition, sentence, definition, account/tale..." (for some of these words, see Audi 1999, 518; for all of them, see Cassin 2004, 747). The extensive semantic scope lends support to the assertion that the interconnection between rationality, scientificity, and objectivity reinforces the idea that rationality encompasses the capacity to elucidate (explain), justify, and subject phenomena to rigorous analysis, meticulous examination.

Thus, rationality is often defined in dictionaries as "the quality of adhering to the laws of reason and being capable of explanation by reason" (Dictionnaire Le Petit Robert 2014). This definition evidently relies on the concept of reason, which is described as "the capacity for judgement by which a person is able to organise and systematise their knowledge and conduct, establishing true relationships with the world" (Dictionnaire Le Grand Robert 2005). It is significant to note that the coupling of rationality and reason, used to define rationality, is a key marker in the long and dynamic history of the concept's maturation. "Its meaning, originally tied to the reasoning subject, appears to have evolved through successive emancipations: first from faith, then from philosophical reason to become scientific rationality, and finally from science to encompass the broader social sphere" (Babou 1999, 408-409).

In social and economic contexts, the concept of rationality serves to "describe, explain, and evaluate the behaviours, actions, and beliefs of social actors" (Boudon 1995, 528). For Gottschalk and Witkin (1991, 122) "the dominant conception of rationality that has evolved in the modem western world, especially in the social sciences, is based on efficiency of means rather than the value of ends, and an individualist rather than a collective or societal orientation". In any case, to say that a person is rational, that is, to attribute a certain rationality to people, is to praise their ability to make good use of reason by adopting effective strategies and principles to achieve their goals. All these nuances reflect the role of rationality as a concept that underpins our value judgements.

In summary, the etymological approach reveals not only the contours of rationality but also the lexical field in which it is embedded: reason, knowledge, method, scientific rigour, and objectivity. As it is often said, to truly understand a concept is not merely to grasp its

[5] In essence, any rational process is predicated on knowledge. Whilst in the theoretical domain, the fundamental objective of reason is knowledge itself, in the practical domain, it is primarily concerned with the success of an action. However, if we are not cautious, this distinction (which is not a separation) can result in a dichotomy between the being and the choice of actions.

meaning but also to establish relationships with other concepts and develop a holistic view. This is the kind of understanding aimed at in the epistemological elaborations that follow.

Epistemological Approaches to Better Grasp the Concept

Epistemologists have sought to define the rationality that underpins the scientific enterprise, with the aim of legitimising the scientific method. This pursuit carries the risk of leading to an overreliance on scientific thinking, as exemplified by scientism (see Turunen, Hirvonen, and Pättiniemi 2023). Furthermore, they have attempted to identify a foundation upon which to construct a firm basis for our knowledge (see, for example, Bouveresse 1998; Eder 2021; Saalmann 2020). Finally, the problem of defining rationality soon arose and became the subject of debate, giving rise to diverse and contrasting theses. To a large extent, the multiplicity of these theses, along with the dissatisfaction and critiques that accompanied them, led to the rightful persuasion that "few questions are more practical or urgent today than how knowledge may be reliably gained and where the limits of certainty lie" (Holton 1998 [1978], 84).

The situation would be incomplete if we did not add that in the background of this urgency lies the instability of the Enlightenment's achievements at the end of the 19th century. The belief in harmony between the speculative and practical uses of reason was called into question, with regard to history (Saint-Sernin 1992, 215-224), as was reason's legitimacy in grasping the absolute or the universally valid truths that define science. While this is the situation upstream, downstream, one might say, without exaggeration, that the scientific world has become something of a *Tower of Babel*[6] in terms of the proliferation and divergence of theories developed to address this urgency. Indeed, "Science is more like a court in which proponents and opponents of theories make arguments and marshal evidence in support of their respective positions" (Lebow 2022, 139).

However, as suggested by our etymological approach, scientific rationality pertains to method (how research should proceed to be scientific), and in this regard, its ultimate meaning can only be illuminated through the analysis of theories that outline the path to objective knowledge. Yet, the approaches are highly diverse, and the difficulty of defining scientific rationality without dissension or debate over boundaries or legitimacy has led Auroux and Weil (1991, 410) to assert that "the history of philosophy coincides with the attempt by rationality to authenticate itself".

René Descartes, one of the founders of modern rationalism, set forth a systematic methodology for attaining, that is a certain knowledge, in his *Discourse on the method* (2006 [1637]), as he had already done in *Rules for the direction of the mind* (1961 [1701]). To achieve this, one must know methodically, which means knowing everything in order, progressing from the simplest to the most complex, and following the rules of the understanding, i.e. reasoning deductively. In short, according to Descartes, the certainty of scientific knowledge (and thus scientific rationality) rests solely on the capacity of reason or, more precisely, the understanding, and not on experience, which is often misleading. Even empirical knowledge of facts, to be authentically scientific, cannot rest solely on the regular observation of phenomena; it must also be derived from reason, which establishes the relationships revealed by the repetitive facts that science seeks to explain.

Descartes's concern with demonstrating how to think in order to achieve scientific knowledge illustrates that the question of scientific rationality, which is at the heart of our

[6] Here, we refer to the image conveyed by the biblical account (Genesis 11: 1-9), which describes the ambitious project of early humanity to build a tower reaching the heavens. According to the narrative, this project ultimately ended with the confusion of languages and the dispersion of the human race across the Earth.

investigation, can only be answered appropriately by focusing on the characteristics attributed to scientific thought (method and object)[7]. Here, we find a clue. On the other hand, the illumination or deep conviction in clear and distinct ideas, which for Descartes constitutes the foundation of scientific rationality, remains unsatisfactory. It is even a disappointing support because "as soon as one seeks to know the real world and act upon it, one discovers that the most coherent, clearest, and simplest ideas are often the falsest" (Bouveresse 1998, 9).

What seems to be a consensus today is that scientific discourse must prove its validity through *empirical*, *rational*, and *public arguments* (Matalon 1996, 22). Indeed, with the rise of epistemology, the question of rationality developed further amidst debates over tests intended to evaluate theories (i.e. discourses that attempt to reconstruct, in some manner, the functioning of a specific sector of reality). Thus, two notions – *verification* (from neo-positivism) and *falsification* (from Popper) – which serve as tests for hypotheses and theories, crystallised the debates (Galavotti 2017, 117). These two notions, which represent normative views of science, synthesise the scientific mode of thought and enlighten us, through their commonalities and divergences, about what scientific rationality ultimately entails.

Verification and *falsification* share commonalities in their methodological approach. On one hand, both serve as means to assess, through factual examination, the extent of universality that hypotheses or theories derived from empirical knowledge can rightfully claim. On the other hand, they provide assurance that the "truth" of an accepted theory, even if not immediately self-evident, is likely to gain the conditional assent of any individual capable of making good use of understanding. In a broader sense, it is of the utmost importance that the assent of all relevant and duly qualified individuals be obtained. This can be achieved through a process whereby the hypotheses are demonstrated to align closely with observations, which can be personally verified by each individual or executed by a competent third party in their presence (Fourastié 1978, 216).

The distinction between *verification* and *falsification* hinges on the underlying commonalities and the ultimate objectives pursued.

Verification is a process of testing and examination, undertaken with the objective of substantiating or proving the veracity of a hypothesis and resulting claims of knowledge. In other words, it is a means of confirming, through confrontation with reality, the indisputable and therefore universal nature of a scientific statement. Verification relies on induction, where a hypothesis or theory, supported by facts within a certain set of observational data, can be deemed both verified and objective, as well as universal, once *peer agreement* is secured.[8] Verification, as a means of control, is first and foremost a guarantee that reality can be known as it is in itself. The upshot of this assertion is that verification serves to safeguard our knowledge from the potential criticism of being uncertain and relative. It thereby provides the foundation for scientific rationality.

From a more fundamental standpoint, when truth is conceived as the concordance between thought (theory) and reality (facts), as pursued through verification, it is more accurate to view it as a property of language rather than of reality itself. The notions of "true" and "false" do not pertain to things in their own right but rather serve as qualifiers for propositions. The intrinsic nature of facts is neither inherently true nor false; rather, it is the

[7] The diversity of objects and methods in science does not preclude the acknowledgment that the scientific method refers to specific norms or criteria that must be followed, which determine the scientific nature of the knowledge produced.

[8] This condition of *peer agreement*, understood as the agreement of those with the necessary training to assess and validate findings within their respective fields of expertise, is also a prerequisite for falsification.

language used to describe them that introduces confusion and thereby blurs their true nature. This is why the Vienna Circle, when addressing the issue of scientificity in relation to verification, shifted its attention toward the logical analysis of scientific concepts and propositions (Colas, Chapuis-Schmitz, and Wagner 2004). As Friedrich Waismann asserted, "the 'verification principle' is no more than a maxim devised to guide our philosophical activity in clarifying the content of a statement" (1945, 134; quoted in Chapuis-Schmitz 2004, 317–318). This project does not limit itself to the domain of metaphysics or ordinary language; rather, it seeks to establish the standards of rigour that are characteristic of scientific language.

> The works of the Vienna Circle and related groups focus on science, which is studied either as a whole or in its specific branches. The concepts, propositions, demonstrations, and theories found in the various fields of science are analysed, not so much from the perspective of its historical development or the sociological and psychological conditions of its activity, but rather from a logical perspective. (Colas, Chapuis-Schmitz, and Wagner 2004, 194)

Indeed, science is a well-constructed language in which reasoning is expressed through words (de Condillac 1780, 188). As Étienne Bonnot de Condillac (1780, 175) noted, "the lack of rigorous demonstration in the sciences is not a flaw inherent to the disciplines themselves, but rather a deficiency in the manner in which scientists express their ideas". This suggests, first, that "language has a role in science *ad intra* but also *ad extra*" (Gonzalez 2021, 23). Secondly, it implies that *we access the values of science when scientific language is used properly* (Gonzalez 2021, 8, 24). Proper use of scientific language entails achieving three key objectives: firstly, univocity in the meaning conveyed, or at least the avoidance of ambiguity; secondly, precision in the details reflected in its content; and thirdly, accuracy in reference to reality, with the ideal being exactness in both terms and statements (Gonzalez 2021, 24-25).

In the context of logical positivism, science is conceived as "the totality of propositions recognised as true, encompassing not only the assertions of scholars but also those of everyday life" (Colas, Chapuis-Schmitz, and Wagner 2004, 194). This conception, which bases science on logic, traces back to Aristotle, for whom science establishes universal propositions and resorts to logic for the sake of argumentation in the pursuit of truth: "Our contention now is that we do, at any rate, obtain knowledge by demonstration. By demonstration I mean a syllogism which produces scientific knowledge, in other words, one which enables us to know by the mere fact that we grasp it" (Aristotle 1960, 31).

From these distant origins of the neo-positivist endeavour, it follows that there is no ultimate difference between verification and logical analysis. Although logical analysis culminates in physicalism (the thesis of the unity of the sciences), the philosophical interest of verification and logical analysis is to define scientific rationality. The involvement of logical analysis in clarifying the notion of scientific rationality will be addressed in the next section.

Contrary to *verification*, *falsification* involves testing a hypothesis to seek to refute it, that is, to establish its falsity in accordance with the logical principle that the universal cannot be proven by examples (no matter how numerous or rigorously reasoned they may be) but can be refuted by a single counterexample. "A scientific theory had to be formulated in a way that made it subject to refutation by empirical evidence" (Lebow 2022, 139). In other words, what should take precedence in science is demonstration, which, according to Popper, is far from being the case with verification. As Miguel Espinoza (1998, 56) notes, "contrary to demonstration, which has a general character, verification deals with particular cases. Hence, the problem of induction". It thus falls upon us to comprehend why Popper contends that, in order to satisfy the requirements of demonstration that science demands, the researcher, in relation to empirical evidence, should refrain from seeking a *confirmation* of their theory. Otherwise, the theory would be reduced to an accumulation of examples and could not, therefore, claim to be rationally certain knowledge, whose objectivity and universality are ensured, as required for scientific statements. It is at this price that science can be perceived "as a set of hypotheses that are tentatively proposed with the aim of accurately describing or accounting for the behaviour of some aspect of the world or universe" (Chalmers 2013, 57).

When scientists conduct experiments, they predict a result (what Popper calls conjecture). If they do not obtain the expected result, they conclude that their theory is erroneous. Their theory is thus refutable. In other words, a statement "is falsifiable if there exists a logically possible observation statement or set of observation statements that are inconsistent with it, that is, which, if established as true, would falsify the hypothesis" (Chalmers 2013, 58). And in the name of the very critique that guarantees scientific rationality, a theory that successfully passes the test cannot avoid "peer review" before being considered "corroborated". Popper thus defines the criterion that distinguishes scientific theories from those that are not. A theory that is reduced to the contents of an individual's subjective consciousness and is never refutable, regardless of the experimental results, cannot be considered scientific. "A theory which is not refutable by any conceivable event is non-scientific" (Popper 2002, 48).

If we admit that the problem of the scientificity of scientific statements is essentially linked to the empirical foundation of science, then verification appears to be a less idealised version of the scientific method than falsification. For, in reality, a result consistent with a prediction confirms the theory (see, for example, Broad and Wade 1983, 16-21; Fourez 2002, 68-77). But verification, insofar as it implies the idea of replication (identical repetition of the experiment to confirm the result of research), is an assertion of principle (Matalon 1996, 103-121). Not all experiments can be repeated, and errors related to the experimenter or even to the instruments may skew the results or interpretations. This is an irrefutable fact; however, it is not the crux of the matter. By inviting us to accept that no theory can be considered established but only hypothetical, Popper is more concerned with the intrinsic flaws or errors in the theories themselves in relation to reality or phenomena. These are the very errors that, according to Popper, render, sooner or later, theories, even when adopted, susceptible to correction. With respect to this issue, the verification principle put forth by logical positivists is unable to circumvent the very conclusion that calls into question its own tenability. This is to say that nothing claiming the status of a scientific law or theory can, in theory, be rationally verifiable. Due to this conception, it has been said that Popper "marks the end of the ideal of certainty in science" (Bouveresse 1998, 29).

We must now return to Gaston Bachelard (2002a, 79), who demonstrated that in science "there can be no first truth. There are only first errors", rather than René Descartes (2006 [1637], 33), who claimed that "the things that we conceive very clearly and very distinctly are all true [...] only certain". Unlike Descartes, who believed in the certainty of indubitable truths, Bachelard (2002b, 24) even suggested that "knowledge of reality is a light that always casts a shadow in some nook or cranny".

For Bachelard, as for Popper, science is not the possession of truth but rather a process of rectification of knowledge, a correction of "first errors" (Gil 1993, 49).[9] Objective truth will be a victory over falsity (for the *verificationist*) and a light cast on error, which reveals itself only after a long and meticulous quest by reason (for the *falsificationist*).[10] At the same time,

[9] The author notes that the definition of truth as "the correction of error" is not, strictly speaking, original, since it already appears in Alain's writings as early as 1927. See Alain 1927, 190, cited in Gil 1993, 190, n. 2).

[10] Dépelteau (2011, 7) concludes his analysis of the Popperian approach in similar terms: "the quest for knowledge thus resembles a crusade against falsehood. And if we never discover truth in all its splendour, at least we will fight error".

reason, in the name of the rationality sought by science, must shift from claims of certain knowledge to the humility of accepting that the relativity of knowledge, far from being synonymous with relativism, is a fact of the greatest certainty. In the end, Popper (2005a, 278-281) argues that the rationality of scientific propositions is fundamentally based on the dynamic nature of science (made possible by the boldness of conjectures and the rigour of refutations) and not on the empirical basis of science, as is the case with logical positivists.

In light of the criteria of verification and falsification, scientific rationality becomes clearer. It first appears as an ideal for scientific activity (achieving more reliable theories) to distinguish itself from ordinary knowledge, and subsequently, as the procedure to follow (requirements to meet) for a researcher's work to be considered genuinely scientific. In this process of research, experimentation (individual and public) and the rigour of reasoning (the strict and logical chaining of ideas) emerge as criteria of scientificity that distinguish the scientific from the non-scientific. In this respect, the different approaches to rationality can be seen as efforts to specify the cognitive aims of the scientific enterprise and to indicate the most effective means to achieve them. It is at this level that scientific rationality raises reservations among some authors and is even challenged by others. The most virulent of these challenges comes from Feyerabend (1993), who argues that scientific rationality is merely a myth – something mistakenly believed to exist. As Bernard d'Espagnat (1990, 6) aptly put it, "in philosophical matters, there are no theorems, and this remains true of the interpretation of the sciences, even if in that field the content of certain theorems cannot strictly be disregarded".

It is often not easy to delineate the boundaries of certain debates or subjects. This observation applies to scientific rationality, for which it would be futile to expect to find in the philosophical tradition a clear, precise, unequivocal, and readable definition that is not ultimately a *stipulative definition.*[11] A definition of this kind can be found in Igor Badou's work, as follows:

> Scientific rationality is generally considered to be a procedure (method, means) applied to the "real" by a thinking subject, based on logical axioms, and aiming at a goal (truth, knowledge) confirmed by a public (the possible intersubjectivity allowing the construction of facts). This minimal definition seems to constitute what we shall call the conceptual core of scientific rationality. (Babou 1999, 409)

Although Igor Badou's definition provides a comprehensive and functional overview, it fails to acknowledge the dynamic and evolving nature of scientific rationality. Given that the very nature of science is characterised by continuous revision and development, it follows that scientific rationality also exemplifies this essential quality. In order to address this issue, we put forward the suggestion that the conceptual core of scientific rationality, as defined by Badou, should be expanded to include *the ongoing process of revision and refinement in the pursuit of knowledge*. This process not only stems from the core principles of scientific rationality but also has the capacity to reshape and influence them over time, thereby aligning with "the traditional link between science's rationality and its method" (Siegel 1985, 517).

With this adjustment, we believe that the definition will become more robust and will align more closely with the perspective articulated by Helena Sheehan:

> We need to forge richer, reconstructed concepts of scientific rationality and scientific progress, in continuity with the older concepts, but incorporating an understanding of

[11] This expression means: a definition that is not linked to the dictionary equivalents but established by convention without being either true or false. For further details, see Hempel 1966, 85-102.

> all that has brought them into crisis, particularly an understanding of the importance of the socio-historical context of science. (Sheehan 2007, 8)

Sheehan does not provide a definition, but rather a perspective that suggests that, in formulating a definition of scientific rationality, it is necessary to keep in mind important epistemological issues. In our view, this framework takes into account the epistemological upheaval that followed the era of the Vienna Circle, which in many ways bears a striking resemblance to the biblical Tower of Babel. The Vienna Circle advocated a unified approach to the study of science and a single language, that of physics. This perspective failed, leaving room for an ongoing debate that continues to shape the landscape of philosophical discourse on science. Harvey Siegel (1985, 517) was right when he wrote: "As a result, many philosophers are either denying science its claim to rationality, or else casting about for a new account of its rationality". In the same way that the biblical story describes a sudden inability of people to understand each other, Kuhn's seminal book *The structure of scientific revolutions* suggests that scientists working under different paradigms can sometimes struggle to communicate effectively, almost as if they were speaking different languages. The Tower of Babel analogy encompasses Kuhn's point, but goes beyond it to challenge unified views of science, particularly in relation to how scientific rationality is placed on secure foundations.

It is our view that scientific rationality, as a requirement that confers scientificity, is associated not with the "why" of knowledge but with the "how" of knowledge that transcends the subjectivity of the researcher to reach that of humanity – verifiable by any person, in keeping with Descartes's famous phrase: "Good sense is the most evenly distributed thing in the world" (Descartes 2006 [1637], 5).

By this, Descartes asserts, as is well known, that the faculty of discerning truth from falsehood is common to all people. But he also subtly invites us not to overlook, as he later explains, that what many people lack is an adequate method of applying this faculty. Descartes thus reminds us that scientific rationality rests on the requirement of a method adapted to the type of object studied, and that any supposed scientific claim must demonstrate that it is based on reasoning that other researchers with the appropriate means can test to confirm (verification) or refute (falsification) its validity.

It becomes clear that the scientific ideal of rationality emphasises *procedural rigour*, *empiricism* (as the tribunal of truth), and *the logical aspect of the scientific approach*, as indicated by the term "logical empiricism" adopted by the Vienna Circle. The logical analysis that was pivotal to the logical empiricist movement (especially the Vienna Circle) may no longer be a central topic of discussion in contemporary debates on rationality, due to substantial critiques, particularly from figures such as Popper (who asserted responsibility for killing logical positivism and the subsequent downfall of the Vienna Circle [Popper 2005b, 98]), Willard Van Orman Quine (in *Two dogmas of empiricism*) and Thomas Kuhn (*The structure of scientific revolutions*).[12] Still, further exploration of its primary tool, logical analysis, is of considerable academic interest.

Logical Analysis: The Cornerstone of Rationality in the Evolution of Thought

As set forth in the preceding section, logical empiricism places a significant emphasis on logical analysis as a central tenet of its philosophical methodology. Given the significant position occupied by this instrument in the tracing of the route for rationality and associated

[12] The two latter authors, among other things, contested the idea that scientific progress could be fully grasped through the lens of logical frameworks.

concepts within the history of thought, a critical examination of this particular tool is worthy of consideration when the subject of rationality is under discussion.

The term "logical analysis" combines two components: "logical" and "analysis". The term "logical" is derived from "logic", a term that is commonly used and may initially seem straightforward. It, in fact, encompasses significant semantic complexity, which can result in superficial interpretations (Cohen, Copi, and McMahon 2016, foreword). Once clarified, however, it allows for a more nuanced comprehension of related terms, such as "logical". By elucidating the subtle dimensions of the term "logic" and undertaking a parallel examination of the concept of "analysis", we can contribute to a discerning comprehension of "logical analysis" and offer insights into its ramifications, strengths and constraints within the sphere of philosophical and analytical discourse.

It is firstly important to note that the conventional association of logic with inference is accurate; yet, it is limited in scope. As Bencivenga (2017, 4: 1) argues, the characterisation of logic as a theory of inference is a biased and restrictive one. He proposes that a more comprehensive understanding of logic, which views it as a theory of *logos* – or meaningful discourse – can facilitate the exploration of a wider range of reasoning and argumentation methods that extend beyond the confines of inference. This observation likely offers an entry point into the work of the logical positivists.

Within this framework, it is pertinent to clarify that the term "logic", translated as "logique" in French, has two different linguistic functions in French. First, "logique" functions as a noun, analogous to its use in English (*logic*), where it refers to the formal discipline concerned with the principles of reasoning. Second, "logique" can also function as an adjective, without any change in spelling, corresponding to the English adjective "logical", describing something that follows or is consistent with the rules of logic. This term, however, is derived from the Greek *logikê*, which is closely related to *logos*, a term that encompasses, as previously noted, "reason", "language", and "reasoning". Something is logical (here, used as an adjective – *logikos* in Greek) when it is rational, reasoned, i.e. when it reveals a coherent chain of reasoning that might even be seen as necessary, whether concerning the development of ideas in thought expressed through language or in the events or things that occur. Defined as a science, "logic is concerned solely with whether a statement is true or false on the basis of meanings assigned to the statement's terms" (Carnap 1966, 177). This consideration positions logic as a science of meaning within the tradition of semantics, a school of thought that focuses on the meaning of words (Coffa 2001, 88-89). The connection between logic and language, already present in the foundation of logic with Aristotle due to the sophists and renewed by neo-positivism in the service of science, justifies the assertion that "all knowledge is expressed in language" (Malherbe 1981, 13). Furthermore, we can add: without language, the transmission of knowledge would likely be impossible. While this does not claim to cover all aspects of logic, we can now move on to the word "analysis".

To analyse means to break down a whole into its constituent parts in order to better grasp the relationships that unite the parts with the whole. Specifically, analysis in ancient Greek philosophy is a mathematical process that involves, in line with its etymology (*analuein*, to "unite" or "unravel"), assuming the problem has already been solved (possessing the conclusion that constitutes the solution) and working backwards to a principle whose necessary consequence is the assumed solution. As in mathematical reasoning, analysis allows one to move from the complex to the simple, so that difficult (or supposedly difficult) questions become easier to resolve. For example, philosophical discourse cannot do without concepts, and this often necessitates a detour through conceptual analysis to understand what we are talking about. In a sense, this is what we have attempted to do with the expression "logical analysis".

Indeed, elucidating each of the two terms in this expression now allows us to define logical analysis as a philosophically inspired method, stemming from mathematics, that consists of identifying the atomic components of complex propositions to clarify thoughts and eliminate superfluous entities. In this sense, it encompasses a range of approaches (Leclercq 2008; Malherbe 1981; Rosier-Catach 2017) from Frege to Quine (Leclercq 2008),[13] which have developed a formal or interpreted language in the philosophical and scientific domains "to express precisely – and perhaps even solve – philosophical problems" (Coffa 2001, 81). In fact, behind "solving philosophical problems" lies a broad agenda that seeks

> to make it possible to express all the propositions of science, or those of a particular scientific domain, in a logically clear language in order to reveal their logical structure, their meaning, the conditions under which they can be recognised as true, their logical interdependencies, and to ensure, as far as possible, the coherence of the entire body of these propositions. (Wagner 2002, 45)

In this way, logical analysis has become a characteristic method of the Vienna Circle's work, aligning closely with *axiomatic logical analysis* (Vernant 1995, 17). This form of analysis focuses on the logical form (internal structure) of propositions and the rules governing their connections to ensure the correctness of scientific reasoning.

Thus, far from being merely an instance of censorship for ordinary language, deemed misleading and imprecise,[14] logical analysis has evolved among philosophers of the Vienna Circle into the means by which verifiability, considered a criterion of meaning and scientificity, is made possible. Hence its involvement in the project to demarcate science (the domain of meaningful statements) from metaphysics (the field of meaningless statements). Popper would later express his opposition to this rigid categorisation by logical positivists and reject, in turn, verifiability as a criterion of scientificity.

Indeed, although Popper, like the neo-positivists, invokes logical analysis to reject the study of invention, unlike them, he shows little interest in language-related issues and never considered the demarcation of science as transcending or excluding metaphysics. On the one hand, he did not believe that reflecting on meaning contributes anything to the understanding of science (Laugier 2002, 969). On the other hand, he advocated the repeal of the "criterion of meaning" (verification) as a "criterion of scientificity". The reduction of the latter to the former, as carried out by the Vienna Circle philosophers (notably Carnap), fails to consider that "meaning does not reside solely in what is verifiable, but also in everything that is intelligible, whether verifiable or not" (Sacchi 2000, 42). In his critique of the Circle, Popper unequivocally concludes that verification is impossible. His argument hinges on the premise that the epistemological foundations of verification, namely "induction" and "the law of probabilities" (the conjunction "and" should not dissolve the connection between the two)[15] fail to withstand the test of logic (Dépelteau 2011, 69-71).

According to the principle of verifiability, a statement is meaningful when it can be shown to be true or false, at least in principle, by experiential means. More precisely, and for the most part, the verification criterion, to be effective – that is, to accredit scientific truth – must confirm that basic propositions (elementary propositions or protocol statements)[16] correspond to empirically verified facts, as revealed by logical analysis. The schema would be as follows: theoretical statements T are linked to observational statements O by semantic

[13] Bruno Leclercq positions Bertrand Russell, Ludwig Wittgenstein, and Rudolf Carnap between the two.
[14] Aristotle sought to make logic a tool for discerning truth from falsehood, with the aim of dismantling the sophists' fallacies. In this regard, a particularly relevant work is Aristotle 1984, 278-314.
[15] The veracity of the law of probabilities is also founded upon an inductive methodology. The law of probability is contingent upon experience to ensure, through the application of mathematical principles and calculations, that under specific conditions there is a high chance of approximating the truth.
[16] Popper made a critical study of this terminology. See Popper 2005a, 31, 40 and 100-105.

rules[17] known as correspondence rules C. This relationship would constitute the meaning of the proposition. This meaning arises, in short, from logical analysis, which has served to break down the proposition into its constituent elements – the "protocol statements". These statements, being in the realm of what can be observed, are subject to immediate verification, in line with the empiricist principle that "among the descriptive terms of science, those that designate publicly observable entities (without using a microscope) are easier to understand than less observable terms" (Jacob 1980, 18). Ultimately, as Paul Scheurer observes, in his preface to (Holton 1982, 6), following Kolakowski, what logical empiricists demand of a scientific theory is "*that it meets at least two criteria: external validation through conformity to facts and internal logical coherence*".

However, scientific knowledge is characterised by its symbolic expression (often presented in mathematical formulas like this one: $E = mc^2$),[18] which allows it to be transmitted and represent the reality that science apprehends. Therefore, in order to pass the verification test, the translation of theoretical language into a language suitable for observation (the language of experience) is a prerequisite. The underlying question is how to convey through words what we understand through equations, without the message of these mathematical formulas losing conciseness and gaining intelligibility.

The variety of answers provided reveals that even if science is, by definition, "shareable knowledge" (Matalon 1996, 23), it uses a very particular type of language (theoretical), whose translation into the language of experience (sensory data) has resulted either in failures or dissatisfaction with the verifiability criterion. Unable to foresee everything, due to various intertwined questions and nuances that emerge, some of these conceptions have proven unachievable.[19]

Through an argument based on logical principles, Carnap concluded that operationalism[20] had failed and preferred to "express the theories of physics in a global language in which the theoretical part of the language would be minimised and the ontological commitments of the logical and mathematical vocabulary would be considerable" (Jacob 1980, 20-24). Thus, in the architecture of the process of scientificity, verification presupposes logical analysis to make credible the idea that, from a set of verified statements, it would be possible to rigorously construct a scientific theory using the procedures of inductive logic. By "scientific theory", we mean "the systematisation of a series of scientific principles and laws into a simpler whole with great explanatory value" (Boisset and Simon 1979, 34). Conversely, scientific theories allow us to predict facts describable by protocol statements, which will be confirmed or refuted through confrontation with experience.

Ultimately, all scientific theories could be reduced to logical-mathematical explanatory systems (the form of the language of theories) and elementary empirical propositions (the

[17] The study of semantics is concerned with the meaning of words. However, in order to achieve its objective, it must not be separated from syntax, which is defined as the set of rules used to link terms. If the structure of sentences does not obey the rules and principles that make up the grammar of a language, it will be difficult to determine the meaning of statements.
[18] The example provided is one of the renowned formulae of relativity discovered by Albert Einstein (1879-1955). This formula establishes a relationship of equivalence between energy (E) and mass (m), where (c) denotes the speed of light. By focusing on the relationships between phenomena, scientific laws have enabled science, since Galileo and the advent of mathematical physics, to move beyond the backtracking to causes that was used to define certain knowledge (Aristotle 1960, I, 2, 71b, 9-11). This has allowed for greater precision in describing and predicting phenomena.
[19] For an account of these different approaches, see Jacob 1980, 20-24.
[20] In epistemology, operationalism represents a pragmatic variant of the criterion of meaning. It is based on the thesis that the meaning of a statement is provided by the set of operations it covers. The American physicist Percy Williams Bridgman (1882-1961) is presented as the leader of this movement.

content of knowledge). This reductive distinction of scientific activity (as historians and sociologists of science would say) privileges the intrinsic content of theories over the circumstances of their establishment (delegated to sociology). The same applies to the definitive logical form of theories compared to the various approaches that led to their formation (relegated to psychology). This distinction, whose validity has been questioned by Quine (1969; 1951) and socio-epistemologists, is the source of the separation established by Reichenbach (1938, 7) and Popper (2005a, 7) between the "context of discovery" (considered to fall under sociology or psychology) and the "context of justification", for which epistemology proposes a normative analysis.

It is worth noting here that our earlier reference to a more serene study of logical analysis when discussing verification now takes on full meaning. Specifically, it becomes evident that the logical analysis developed within the context of the verification criterion has been employed to serve the purpose of substantiating the neo-positivist thesis that eschews the study of scientific discovery. The neo-positivist argument has been subjected to considerable opposition, notably from scholars such as Gerald Holton (1988 [1973]; 1998 [1978]) and Toulmin (1972), among others, who have called for a move away from the exclusive reliance on the methods of mathematical logic. Such critiques call for a more constructive engagement with philosophical, historical, and sociological inquiries, moving beyond the formal analysis of propositional systems and their relations (Toulmin 1972, 387). These challenges seek to expand the scope of enquiry to encompass a more profound investigation of the contextual and epistemological foundations of scientific knowledge.

Upon closer examination, it makes sense to uphold that epistemology as a philosophical discipline must be distinguished from both psychology and logic. If the latter (logic) is more concerned with justification than the former (psychology), as demonstrated by the Vienna Circle, is this not because justificatory mechanisms fall under formal or mathematical logic? However, this is a debate of its own within the epistemological discourse, and one that is beyond the scope of this paper.

Conclusion

The discussion in this paper suggests that the passage from *rationality* to *scientific rationality* is not a straightforward refinement or the identification of a stable epistemic core. Instead, it is indicative of an endeavour to impose methodological discipline on a concept whose semantic scope and philosophical history resist unification. Scientific rationality does not eliminate the indeterminacy of rationality; rather, it regulates it.

This is achieved through the implementation of methodological constraints, which include requirements for public justification, logical coherence, empirical accountability, and the capacity for critical revisability. These constraints do not yield a definitive definition of rationality, but they establish the conditions under which rational claims may be recognised as scientific. In this sense, scientific rationality is less a doctrine than a practice, one that gains its legitimacy not from certainty, but from its capacity to organise inquiry, correct error, and sustain intersubjective agreement (Merton 1973; Ravetz 1971).

The recurrent temptation to view scientific rationality as an impregnable foundation stems from a desire for epistemic security. Conversely, the image of fragmentation, expressed through metaphor of Babel, reflects the undeniable plurality of methods, languages, and standards at work within science. The analysis developed here supports neither extreme. Scientific rationality is neither a unified fortress nor a mere aggregation of incompatible practices. It is a historically situated and normatively regulated enterprise whose coherence is procedural rather than doctrinal (Laudan 1978).

This conclusion has two implications. *Firstly*, it cautions against attempts to define rationality in purely substantive terms, as if its meaning could be fixed independently of practice. *Secondly,* it undermines sceptical claims that deny science any distinctive rationality due to methodological diversity. The absence of a winning definition does not disprove scientific rationality. It is actually what makes it so important to keep talking about it.

Understood in this way, scientific rationality is inseparable from the dynamic nature of science itself. Rather than being associated with certainty, its rationality has to do with the disciplined manner in which disagreement, error and correction are made productive. Ultimately, this is what distinguishes scientific rationality from other forms of rational thought and justifies its enduring epistemological significance.

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