Article

The Language of the Scientific Revolution: A Linguistic Thesis on the Origins of the Modern Science[1]

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Abstract:

This paper aims to demonstrate that a qualitative change in the use of language to codify social practices and technological developments was an essential point in the construction of the so-called scientific revolution. In other words, alongside the social and technological settings developing in the European context from the fifteenth to seventeenth centuries, the pragmatic-linguistic codifications that emerged in this process were essential for the construction of modern science. The role of language in this process, which is understood from this pragmatic viewpoint, is called here the *linguistic thesis on the scientific revolution*.

Keyword: Linguistic thesis; Language and science; Scientific revolution; Modern science, Wittgenstein

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> *What a Copernicus or a Darwin really achieved was not the discovery of a true theory but of a fertile new point of view.*[3]
> Ludwig Wittgenstein

Introduction

Around the seventeenth century, the European way of life changed profoundly and with exponential implications that subsequently spread throughout the world. There were social, economic, political, and technological transformations so radical in this context that enabled the rise of modern science. In turn, science contributed enormously to the profound change

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[3] "Das eigentliche Verdienst eines Kopernicus oder Darwin war nicht die Entdeckung einer wahren Theorie, sondern eines fruchtbaren neuen Aspekts" (Wittgenstein, 1980 [1977], 18).

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in human knowledge, leading Alexandre Koyré to characterize this singular event as a "scientific revolution".[4] Therefore, whether or not we give credence to the Franco-Russian historian of science's statement about modern science as a radical break from the past, or accept the idea of a "continuous" and "progressive" transformation (Duhem, Crombie), or even an "evolution" (Fleck) of knowledge as advocated by other authors, it is undeniable that the advent of modern science affects us to this day. In other words, it is a truism that the scientific revolution has indelibly changed human life.

I assert, however, that the use of the expression "scientific revolution" does not necessarily advocate Koyré's thesis about this radical rupture, but is merely a useful "label" or rubric that has become usual and, in different ways, aggregated to this series of social, technological, and epistemological transformations that culminated in the construction of modern science. Whether this change was an abrupt "revolution", or a continually prepared "evolution", is a matter of fact that has represented some "disruption" or "deflection" of the historical process and, as a consequence, created modern science.

What would have caused this great transformation of knowledge in that context? In other words, what would have caused modern science? Or the scientific revolution as characterized by Koyré and his followers? Admittedly, there were multiple factors, and in this sense, possibly, modern science was the result of this whole set of changes in the values and practices of the medieval world. Would it be possible, however, to point out a determining factor or, at least, more prominently in conducting this process? Did science develop intrinsically, or did factors external to it have a determining influence? These were issues addressed by the debate internalism versus externalism between the 1940s and 1960s.[5]

For authors labeled as externalists, such as Edgar Zilsel, social and technological factors – in the new economic context brought on by capitalism – allowed for the construction of modern science by uniting the practical knowledge of higher craftsmen (or artist-engineers) with the theoretical knowledge of philosophers and humanists (Zilsel, 2000 [1994], 6).[6] On the other hand, for Koyré, labeled as the highest representative of internalism, such social and technological factors would be secondary and science would be the first and foremost result of a "metaphysical attitude" (Koyré 1966 [1939], 13). Since ancient Greece, science would be essentially *theoria* (Koyré 1973 [1966], 399). Moreover, Koyré argued that if technical elements were fundamental to the scientific revolution, it would have occurred with the Roman engineers a thousand years earlier (Koyré 1973 [1966], 75). In affirming the hegemony of the theory over technological and social issues, the Franco-Russian historian concludes that the invention of the clock, for example, was due much more to the ideas of scientists (Galileo, Newton, and Huygens) than to the excellent work of artisans who manufactured this timepiece (Koyré 1971 [1961], 354, 357). Finally, for him, theory prevails over technique and social issues, which would have secondary contributions.

A decisive point made here is that, to some extent, this debate between internalism and externalism, which sought to understand the foundation of modern science, did not reach a consensus – no matter how great the effort[7] – because there is a lack of analysis of the issues concerning language use in that proper context. Language is an essential element that provides more satisfactory answers as to understanding "how" modern science arose. Although the question of language has already appeared in some interpretations on modern

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[4] According to Shapin, "the phrase 'the scientific revolution' was not in common use before Alexandre Koyré gave it wider currency in 1939" (Shapin 1996, 2).

[5] Shapin suggests the dates of this debate between the end of World War II and the end of the Cold War (Shapin 1992, 333).

[6] Paolo Rossi developed some essential aspects of the Zilsel thesis in *I filosofi e le macchine 1400-1700* (Rossi 2009 [1962]).

[7] In a sense, Kuhn's classic book, *The Structure of Scientific Revolutions*, is a somewhat successful attempt to resolve this debate (Kuhn 1970 [1962]).

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science before the mid-twentieth century, indeed the historiography of science began to assimilate the issue of language with the developments of the so-called "linguistic turn". For that purpose, it was especially important the philosophy of the later Wittgenstein, as well as more categorical works that affirmed the relevance of social aspects in the construction of scientific knowledge.[8] The later Wittgenstein, especially in his *Philosophical Investigations* (2008 [1953]), is a central figure in the pragmatic approach of language. As regards to the assimilation of language in the historiography of science, the Austrian philosopher was also a thinker with significant influence on Kuhn (1970 [1962], 2000), and Shapin and Schaffer (1985). Similarly, I will consider Wittgenstein's philosophy of language – with its notions of "language games" (*Sprachspiele*), "form of life" (*Lebensform*), and "grammar" (*Grammatik*) (Condé, 1998, 2004, 2018) – to propose a linguistic thesis for the scientific revolution.

In other words, although authors such as Kuhn, Shapin and Schaffer have already assimilated Wittgenstein's philosophy to understand the history of science, their results do not seem to have reached all possible implications, especially regarding to the advent of the modern scientific revolution. Indeed, what I am trying to demonstrate is that, from the elements put forward by Wittgenstein's work, it is possible to deepen one's understanding of what the scientific revolution was and, consequently, the production of scientific knowledge in and of itself.

According to the linguistic thesis, starting from the interactions between social and new technologies in the context of emerging capitalism, as presented by Zilsel, we can go further in understanding that the pragmatics of language played a very relevant role in the conduct and organization of this production process of our technical and theoretical knowledge of society and nature, as well as of the use we have made with this knowledge. In a sense, one can argue that modern science is the result of a new pragmatic linguistic order or a new codification of the process of knowledge production based on this social and technological context, uniting practical and theoretical knowledge, as postulated by Zilsel. Thus, the linguistic thesis can be an excellent instrument for assessing "how" engendered the elements are that made the scientific revolution possible.

Finally, it is important to acknowledge that understanding the active role of language codification in this process of scientific knowledge production is very important not only for its historical aspects, but also because the process of making science is still linguistically similar to what engendered the rise of modern science. Considering how the scientific revolution produced knowledge allows us to understand how science has developed historically and, as a consequence, the linguistic thesis can also be an excellent instrument to understand the science of today.

In aiming to understand the problem of language in the production of scientific knowledge, I will first analyze how some significant authors of the historiography of science understood the issue of language. Then I will work on the idea of the linguistic thesis on the scientific revolution. By addressing the issue of language discussed by these authors, the purpose is not to approach their works as a whole – an impossible task for an article – but to delineate how the problem of language appears in the historiography of science. And, finally, I will develop the linguistic approach to understanding the scientific revolution.

The Problem of Language in the Historiography of Science

Theses about the construction of modern science became recurrent in the twentieth century. Several historians, sociologists, and philosophers have elaborated different theses as to what could have produced the scientific revolution in that context. However, even when they

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[8] Although Kuhn's work gave more visibility to the social perspective in understanding scientific knowledge, this point was already defended by authors such as Fleck, Zilsel, Hessen, Grossman, etc.

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made references to the issue of language, these authors did not place it as a central point in the process. If one analyzes the second half of the twentieth century, after the consolidation of the linguistic turn, one can see a development of language's role in the historiography of science. Language became progressively present in the analysis of scientific knowledge, although this movement does not appear to have reached all of its complexity yet. Thus, throughout the twentieth century, authors such as Burtt (1925), Fleck (1935), Kuhn (1962, 2000), and Shapin and Schaffer (1985) analyzed the issue of language. And clearly, one can see that while Burtt and Fleck cared about language, which they referenced in their writing before the linguistic turn, both did not feel the need for a more systematic treatment of it. They did not highlight language as a central tool for elucidating the production of scientific knowledge.

Subsequently, Kuhn, and Shapin and Schaffer – already inserted in a context in which the linguistic turn was already present – made great strides towards clarifying the issue of language as an essential element in the construction of science. Finally, all these authors, throughout the twentieth century, gave us excellent reasonings to think about the problem of language in the development of scientific knowledge, although, they have not yet achieved all the possible success in their analysis, especially concerning the advent of the scientific revolution. In what follows, I will address aspects of these abovementioned authors' work regarding language so as to map how the issue of language has evolved in the historiography of science. From what they have already presented, we can go further to elucidate the role of language in the construction of scientific knowledge, especially concerning the episode of the scientific revolution.

Burtt and the Language at the Service of Metaphysics

Already in the first half of the twentieth century, one can see explicit references to language in a classic text such as Edwin Burtt's, *The Metaphysical Foundations of Modern Physical Science*, edited in 1925. Although Burtt's central thesis states that metaphysics (or the change from medieval to modern metaphysics) was the critical point in the construction of modern science, it is not very clear as to what he exactly means by metaphysics. Unlike Koyré, for whom metaphysics is linked to Cartesian *mathesis universalis* or the Platonic ideas that support the foundations of mathematics as the epicenter of the scientific revolution (Condé 2017), in Burtt, perhaps, one can understand metaphysics – almost in a cultural sense – virtually as a diffuse set of beliefs and values of a given historical period. Thus, for Burtt, modern science would be the result of this change of metaphysics or transformation of the beliefs of medieval society to those of modern society (Burtt 1925, 2). According to Burtt, medieval cosmological ideas would have been replaced with an ethical-social conception in which concepts such as "progress", "control", and the like (Burtt 1925, 3) find their meaning when one follows the "metaphysical notions" of the modern thought. And this is how Burtt concludes, similar to Koyré's position,[9] that what happened at the beginning of modern science was a change of metaphysical conception of the natural world that transformed the thinking of medieval man into that of modern man (Burtt 1925, 5).

In other words, if we understand Burtt's notion of metaphysics as a set of beliefs, the changes in beliefs and the attitude toward them led to the need to develop a new understanding of the nature's working. And something central to Burtt's conclusion is that it

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[9] Besides having a broader notion of metaphysics than Koyré, for Burtt, metaphysics is a "scaffold" that provided the foundation of science and would have fulfilled its role after science arose. In contrast, Koyré criticizes Burtt and maintains that metaphysics is an element that remains present in science even after its consolidation (Koyré 1971 [1961], 255). Like Koyré, Burtt also referred to this metaphysical change as a "revolution" (Burtt 1925, 16).

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becomes necessary to use a new "language" and ideas to express this new metaphysics. "Modern philosophers have been endeavouring to follow the ontological quest in terms of a relatively new background of language and a new undercurrent of ideas" (Burtt 1925, 13). For him, the terminology of the medieval world no longer explained the modern world. Therefore, with its new metaphysics, modern period (Newton) has established precise mathematical meanings for concepts such as "force", "mass", "inertia", as well as giving new meanings to old concepts such as "space", "time", "movement" (Burtt 1925, 20). According to the author of *The Metaphysical Foundations of Modern Physical Science*, this new language will define modern man's new relations with the objects of his knowledge, which is very innovative for the year Burtt is writing. However, shortly after, the role of language is reduced to metaphysics when he points out that the answers to modern scientific questions about space, time, and matter, and the new relationships to objects are what conclusively "constitute modern metaphysics" (Burtt 1925, 21).

We realize, therefore, that even though Burtt has a place for language, he eventually understands it in the context of his metaphysical project. Language is a simple adjunct to metaphysics. Indeed, the questions about language as it will be consolidated in the linguistic turn were still very incipient in the context of the 1920s in which Burtt wrote.

Fleck and the Ordinary Language versus Logical Language

In Fleck's now-classic book, *Genesis and Development of a Scientific Fact*, edited in 1935, one can see several references to language. Generally speaking, Fleck attaches great importance to ordinary language in the production of scientific knowledge, opposing the logical language supported by the Vienna circle, particularly by Carnap. As a central point, for Fleck, a logical and empirical language cannot be conceived without incorporating the social aspects (Fleck 1979 [1935], 50, 177). Long before the linguistic turn established the relationship between language and the pragmatic aspects of the social, Fleck already understood that the relationship between these social aspects and language was paramount to the understanding of science. Thus, unlike Burtt, who exactly a decade earlier connected language to metaphysics, Fleck related social elements and language to reach an adequate understanding of the production of scientific knowledge. According to the Polish thinker, language and social practices unite the "thought collective" (*Denkkollektive*) that produces knowledge or the "thought style" (*Denkstil*) in a specific period.

> Any kind of learning is connected with some tradition and society, and words and customs already suffice to form a collective bond. Cognition is the most socially-conditioned activity of man, and knowledge is the paramount social creation. The very structure of language presents a compelling philosophy characteristic of that community, and even a single word can represent a complex theory. (Fleck, 1979 [1935], 42)

In addition to attributing to the language this role of a unifying the "thought collective", Fleck asserts that language in itself has no meaning, but only in the context of knowledge production (thought collective) the meaning emerges. "Word as such do not have fixed meanings. They acquire their most proper sense only in some context or field of science" (Fleck, 1979 [1935], 53). Moreover, language not only has an importance in the dynamics that will lead to the construction of concepts and theories (even if they are not eternal) that will unify the thought style in our thought collective, but, after the acceptation of a scientific theory, language continues to play a significant role in the process of consolidating science. Language helps in forming the "system of opinion" or the "harmony

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of illusion" (Fleck, 1979 [1935], 27) to unify the scientific community. Fleck asserts that "words which formerly were simple terms become slogans; sentences which once were simple statements become calls to battle" (Fleck, 1979 [1935], 43). Therefore, language is fundamental in the thought style's creation by formulating its specific vocabulary – terminologies – which, from there, will help in the maintenance of science, stabilizing the thought style of a thought collective.

> A closer investigation of thought style and of the general social characteristics of thought collectives in their mutual relations can be made by concentrating upon stable thought collectives. Such stable (or comparatively stable) thought communities, like other organized communes, cultivate a certain exclusiveness both formally and in content. A thought commune becomes isolated formally, but also absolutely bonded together, through statutory and customary arrangements, sometimes a separate language, or at least special terminology. (Fleck, 1979 [1935], 103)

More than unite the thought collective internally (intracollective), language is one of the crucial elements for connecting different thought styles (intercollective) and even different historical periods, thus establishing a tradition in the production of knowledge. Concepts or notions that Fleck calls "proto-ideas" or "pre-ideas" in language (Fleck, 1979 [1935], 23, 26) pass through different thought styles over time, such as the ideas of syphilis or atoms. For Fleck, language is thus a connecting link running through different thought styles. "Whether we like it or not, we can never sever our links with the past, complete with all its errors. It survives in accepted concepts, in the presentation of problems, in the syllabus of formal education, in everyday life, as well as in language and institutions" (Fleck, 1979 [1935], 20). With this ability to transit between different collectives, language is not only the element that unites a collective or connects it to other thought collectives (or other thought styles), but it has the plasticity to reshape or create new meanings when these concepts migrate or circulate among different thought collectives (*interkollektiven Denkverkehr*).

> Words as such constitute a special medium of intercollective communication. Since all words bear a more or less distinctive coloring conforming to a given thought style, a character which changes during the passage from one collective to the next, they always undergo a certain change in their meaning as they circulate intercollectively. One could compare the meaning of the words "force", "energy", or "experiment" for a physicist, a philologist, or a sportsman. (Fleck, 1979 [1935], 109)

Finally, for Fleck, language plays a crucial role in the final constitution of what is considered a scientific fact or what is understood by scientific objectivity.

> This tendency to reify and objectivize the conceptual creations of scientific thought arises, as has already been described, during the migration of ideas throughout the collective and is inseparably bound up with it. Graduated in several steps, it begins with statements by different scientists as well as the historical development of a problem, so that it becomes depersonalized. Special expressions or "technical terms" are introduced. To these are added special symbols and possibly a whole sign language such as is used in chemistry, mathematics, or symbolic logic. Such a lifeless language guarantees fixed meanings for concepts, rendering them static and absolute. (Fleck, 1979 [1935], 144)

However, although Fleck had excellent and innovative ideas about language in the construction of scientific knowledge, the author of *Genesis and Development of a Scientific Fact* did not think that he should do a better systematization of language or create a type of

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language theory that could highlight the real role of language in science production. He believed that the simple understanding of natural language (as opposed to logical language) in this process of science production would solve the problem of knowledge.

In a way, the separation between "context of discovery" versus "context of justification" presented by the neopositivist philosopher Hans Reichenbach (1938), shortly after Fleck's work appeared, would include sociological and linguistic remarks about science in the field of the "context of discovery". All the same, this was perhaps one of the factors (among many) to move Fleck's work away from the historiography of science for many years.[10] Almost three decades later, Kuhn will revive Fleck's book, but unfortunately, the American philosopher will not give much value to the issue of language as proposed by the Polish thinker, assimilating only the social aspect present in the production of scientific knowledge (Kuhn, 1970 [1962] vii).

Kuhn and the Lexicon of Science

Thomas Kuhn incorporated aspects of the issue of language into his conception of the history of science already in his classic book, *The Structure of Scientific Revolutions*, edited in 1962. There, albeit indirectly, some elements appear in this sense – in particular, in his references to Wittgenstein (Kuhn 1970 [1962], 44-45) in the chapter "The Priority of Paradigms" – but it will undoubtedly be with his later concept of lexicon that he will assume the full importance of language for understanding the process of producing scientific knowledge. Thus, in his following texts, language occupies his interest progressively until his death in 1996. In 1995, Kuhn stated: "much of my thoughts these days goes to language" (Kuhn 2000, 259).[11]

In a pragmatic viewpoint, still strongly inspired by Wittgenstein,[12] for Kuhn, the lexicon is precisely the way information about the language and the world is distributed in our interactions and representations of the world. Unlike what he previously affirmed in his famous book; a scientific revolution would now be a "linguistic revolution" in which knowledge about nature comes with the language. As Kuhn exemplifies in Planck's case,

> Revolutions were accompanied by changes in the way in which terms like "motion" or "cell" attached to nature. In this example there was actually a change in the words themselves, one that highlights those features of the physical situation that the revolution had made prominent. When Planck around 1909 was at last persuaded that discontinuity had come to stay, he switched to a vocabulary that has been standard since. Previously he had ordinarily referred to the cell size ε as the energy "element". Now, in 1909, he began regularly to speak instead of the energy "quantum". (Kuhn 2000, 28)

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[10] Ironically, it was in this Reichenbach's book that Kuhn found the reference to Fleck's book (Kuhn 1979, vii).

[11] The importance of language in Kuhn occurs progressively in the following texts: "What are Scientific Revolutions?", "Commensurability, Comparability, Communicability", "Possible Worlds in History of Science", "The Road since Structure", "The Trouble with the Historical Philosophy of Science" and "Afterwords" from the book *World Changes: Thomas Kuhn and the Nature of Science*, organized by Paul Horwich, in 1993. These texts appeared separately between 1982 and 1993 and are now part of the book *The Road since Structure*. From here, all references follow this edition (Kuhn, 2000).

[12] Kuhn recognizes Wittgenstein "recurrent role" in his "philosophical development" (Kuhn 2000, 72), and makes many direct references to Wittgenstein's concepts, such as language games, form of life, and uses (Kuhn 2000, 62, 63, 100, 244, 245).

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In a sense, one can say that Kuhn has moved towards a linguistic turn with which he has tried to solve old problems presented in his theory of science in *The Structure of Scientific Revolutions*. According to this new linguistic viewpoint, unlike the idea of radical rupture between scientific concepts or worldviews associated with the notion of incommensurability of the paradigms shown in his book, the idea of scientific revolution should now be seen not as a radical rupture but as a change of language. The incommensurability would focus much more on difficulties between the language of different groups or between present and past scientific theories – now called lexicon by him stead of paradigms – than an impossible overlap between these groups, such as the idea of a gestalt switch made us believe (synthesized in the duck-rabbit gestalt figure), or even his conception of paradigm shift or scientific revolution.

Among the problems brought about by the concept of paradigm, perhaps one of the most important has been the need to answer the following question: how is one paradigm incommensurable with another, but still able to understand the other? It will be with the lexicon theory that Kuhn will try to solve this problem. The incommensurability exists because these different groups build their vocabularies that give access to different possible worlds. "To possess a lexicon, a structured vocabulary, is to have access to the varied set of worlds which that lexicon can be used to describe" (Kuhn 2000, 61).

Thus, the incommensurability between lexicons would no longer mean any overlap between them. What exists are varying degrees of linguistic differences. However, according to Kuhn, understanding different lexicons requires not only a superficial translation of concepts from one area to another but an extension of a complete network of concepts from one area to another. This is not a process of "translation" (Kuhn 2000, 59), but of "bilingualism" (Kuhn 2000, 93, 238). In translation, to bring understanding from one area of knowledge to another, we organize the conceptual field from one area to another without necessarily both areas having a mutual understanding of all the nuances of the conceptual network of each lexicon. In bilingualism, the same individual dominates both lexicons. And, as the holder of this expertise, he or she understands the nuances of each lexicon. Finally, in bilingualism – unlike translation – it is possible to reconstruct, from our lexicon, the foreign lexicon.

Kuhn, however, turns away from an entirely pragmatic perspective by approaching, at least, a metaphysical vocabulary. To make the connection between different lexicons possible, Kuhn concludes that his theory presupposes the Kantian notions of categories and *Ding an sich*. "The position I am developing is a sort of Post-Darwinian Kantianism. Like the Kantian categories, the lexicon supplies preconditions of possible experience" (Kuhn 2000, 104).

The Kuhnian lexicon would, therefore, give the "conditions of possibility" to achieve knowledge of natural phenomena. This would make knowledge of the world to some extent dependent on human perception, but, as with Kant, not completely (because they would rest on the ineffable). To be specific, Kuhn further emphasizes his Kantian position by postulating that what guarantees the possibility of change among lexicons is some kind of *Ding an sich*. The North American philosopher states: "Underlying all these processes of differentiation and change, there must, of course, be something permanent, fixed and stable. But, like Kant's *Ding an sich*, it is ineffable, undescribable, undiscussible" (Kuhn 2000, 104).

Kuhn, however, attempts to mitigate the metaphysical nature of the Kantian concepts of categories and *Ding an sich* by giving them historical and social aspects, "but lexical categories, unlike their Kantian forebears, can and do change, both with time and with the passage from one community to another" (Kuhn 2000, 104). Nevertheless, this Kantian position ultimately limits Kuhn's epistemology, since he does not ground them directly in the nature, social and technological contexts of knowledge production, but instead link them to the Kantian metaphysics of the ineffable. In other words, Kuhn advances to understand

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language as an essential aspect in the production of scientific knowledge but fails to give his theory of lexicon a sufficiently pragmatic stance and ultimately resorts to a metaphysics of the ineffable, indescribable, and indisputable to justify it.

Shapin, Schaffer and the Experimental Form of Life

After Kuhn's classic book, *The Structure of Scientific Revolutions*, one of the most impactful books on the historiography of science was *Leviathan and the Air-Pump: Hobbes, Boyle and the Experimental Life* by Shapin and Schaffer, edited in 1985. Although the authors define the book as "an exercise in the sociology of scientific knowledge" (Shapin and Schaffer 1985, 15) linked to the "Strong Program" in different passages, they based the book's proposal directly on Wittgensteinian notions of "form of life" (Shapin and Schaffer 1985, 18, 20, 22) and "language games" (Shapin and Schaffer 1985, 49, 51, 67), thus taking an approach based on the pragmatism. By addressing this controversy between Hobbes and Boyle concerning the existence of the vacuum – in the epicenter of modern science in the seventeenth century – according to the authors, his intention was to understand the internal logic of the experimental "form of life".

According to Shapin and Schaffer, in his *New Experiments*, Boyle did not create an epistemology but established rules of procedure to teach the experimental philosopher how to deal with "practical matters of induction, hypothesizing, causal theorizing, and relating of matters of fact to their explanations" (Shapin and Schaffer, 1985, 49). In this way, Boyle established an "experimental narrative" (Shapin and Schaffer, 1985, 63), that is to say, more than conducting his experiments, he created an experimental "language game" and an experimental "form of life" (Shapin and Schaffer 1985, 49, 51) which involves not only the production device of experiments in itself (the air pump mechanism), but all the social and linguistic (collective) developments necessary for the consolidation of science. Indeed, to produce experimental knowledge, or to generate matter of facts, it is required to establish a set of conventions that are linguistic and social. Only one experimental philosopher who accomplishes the experiment cannot validate a scientific fact. Only the collective of members can provide recognition of a scientific fact. As a result, this validation is achieved through the linguistic and social rules of the collective. In other words, the fact is not only about performance, but "upon the assurance of the relevant community that they had been so performed" (Shapin and Schaffer 1985, 55).

The uses of language obeying a convention, among other things, indicate whether an experimental philosopher takes part in a community (Shapin and Schaffer 1985, 70). Therefore, linguistic and social practices define the members of the community. So more than "speak", the members "act" in this collective according to its rules. Following a Wittgensteinian pragmatics viewpoint, the authors state: "the ultimate justification of convention does not take the form of verbalized rules. Instead, the 'justification' of convention *is* the form of life: the total pattern of activities which includes discursive practices" (Shapin and Schaffer 1985, 52).

To outline these collective social and linguistic practices of the new experimental form of life created by Boyle, the authors of *Leviathan and the Air-Pump* established three different concepts of technologies that, according to them, would be present in the process of scientific knowledge production. The three technologies are: "material technology", "social technology" and "literary technology". Starting from the analysis of the controversy between Boyle and Hobbes about the air pump, the *big science* of the XVII century (Shapin and Schaffer 1985, 38), the authors define their three conceptions of technologies as follows:

> A *material technology* embedded in the construction and operation of the air-pump; *a literary technology* by means of which the phenomena produced by the pump were

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made known to those who were not direct witnesses; and a *social technology* that incorporated the conventions experimental philosophers should use in dealing with each other and considering knowledge-claims. (Shapin and Schaffer 1985, 25)

To this extent, more than material technology or material technical device (the air pump), literary technology, and social technology are, according to Shapin and Schaffer, essential "knowledge-producing tools" (Shapin and Schaffer 1985, 25). In other words, to produce science is equally important, along with the apparatus of material technology, the use of other technologies that establish the *conventions* upheld by the scientific community (social technology) and to define the mechanisms of transmission of scientific knowledge (literary technology). Finally based on these technologies, they synthesize what was accomplished in the book: "We identify the technical, literary, and social practices whereby experimental matters of fact were to be generated, validated, and formed into bases for consensus. (…) we discuss the social and linguistic practices Boyle recommended to experimentalists" (Shapin and Schaffer 1985, 18). One can realize that similarly to Fleck and Kuhn, they affirm the interconnection between linguistic and social practices for the definition of scientific knowledge.

Beyond producing the air pump with its material technology, the role of literary technology was to help create an experimental community. For the authors of *Leviathan and the Air-Pump*, "Boyle's literary technology dramatized the social relations proper to a community of experimental philosophers. Only by establishing right rules of discourse could matters of fact be generated and defended" (Shapin and Schaffer 1985, 69). The "rules of discourse" set out the language and practice to be followed by members belonging to the community or experimental form of life. In this sense, for the authors, Hobbes and Boyle, in following different rules of discourse, belonged to two different forms of life. Thus, they followed different literary technologies in considering the air pump experiment. As the authors point out by analyzing Hobbes and Boyle concerning the air pump,

> The difference between Hobbes and Boyle on cohesion was not, therefore, a difference in mechanism or a difference in their attitudes towards the *horror vacui*: both embraced the former and abominated the latter. It was a difference in conceptions of proper speech about such phenomena, and, therefore, a difference in exemplifying how the natural philosopher was to go on. (Shapin and Schaffer 1985, 91)

As in Fleck and Kuhn, one can see that, for Shapin and Schaffer, knowledge takes place in a community or a collective (Shapin and Schaffer 1985, 56) being linguistic and social. However, rather than stressing the linguistic and social character of knowledge, at the conclusion of the book, Shapin and Schaffer go in the other direction by stating that knowledge is eminently political. Regardless of whether Boyle was considered by several historians of science as the father of the experimental life, for Shapin and Schaffer, this would not be the point in the history of science they sought to make. For them, rather than being exclusively scientific, "the solution of the problem of knowledge is political" (Shapin and Schaffer, 1985, 342).

Boyle's new scientific proposal would share, according to the authors, with the new political order instituted by the "restoration" of monarchical power, the same form of life that supported the ideal of an open and liberal society. This new political organization should also be the space for building the then nascent science. The laboratory, like the space for the construction of useful knowledge, belonged to the same order brought about by political restoration. The authors end the book by concluding: "we put ourselves in a position to realize that it is ourselves and not reality that is responsible for what we know. Knowledge, as much as the state, is the product of human action" (Shapin and Schaffer 1985, 344).

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However, by defending this political position – beyond the linguistic and social aspects in their interaction with the material technology for the production of facts – the authors ended up turning to epistemological relativism in which the criterion of fact production becomes ultimately political. The political instance would define whether knowledge is validated or not. "The form of life in which we make our scientific knowledge will stand or fall with the way we order our affair in the state" (Shapin and Schaffer 1985, 344). Prominent authors like Thomas Kuhn have criticized this relativist shift that, by overemphasizing the political aspect, would be downplaying nature's role in the process of producing scientific knowledge.[13]

Although it is not my aim to criticize this fantastic book and only draw attention to the issue of the language it presents, I would like to reiterate a point. Indeed, the political aspect can be an instance that inhibits or stimulates the production of scientific knowledge, thus political elements are a "necessary condition", but not a "sufficient condition" for the production of knowledge. These sufficient conditions, as the authors also demonstrated, are in the social and linguistic practices that create the material technology for understanding the interactions between mankind and nature. Finally, these experimental language games would be the epistemological parameters for the definition of knowledge, and not political language games, even though the two have, to use a Wittgensteinian expression, "family resemblances" (Wittgenstein 2008 [1953] §§ 67, 77, 108).

The Grammar of the Scientific Revolution

The linguistic thesis on the scientific revolution seeks to affirm that language, understood in its pragmatic conception – especially from the perspective of the later Wittgenstein – was a crucial element that enabled the production of scientific knowledge in the scientific revolution. In other words, language began to play a coordinating role in the processes of production of the new technological know-how and social orders presented by emerging capitalism. This new role of language has enhanced the dialogue between techniques and theory – also modifying the theory itself. The theory thus starts to ground the scientific practices – reciprocally anchored in these techniques and social orders – finally establishing the modern scientific revolution.

As I tried to demonstrate from the authors analyzed, language has been progressively incorporated by the historiography of science since it became an academic discipline. We can learn from Burtt – regardless of his metaphysical project – that language plays a vital role in the way we organize our objects, whether technical or scientific, even though Burtt privileges scientific objects with a metaphysical halo. We have seen with Fleck that it is practically impossible to dissociate language from the social in the production of scientific knowledge. We only do science, among other material assumptions, from a social context using language to create and express concepts and theories, and one consolidates scientific practices by the specific terminologies that language provides us. Along the same lines, according to Kuhn, we only know the world because we establish the use of language for it. That is to say, we create a lexicon from where we interpret it. In the scientific lexicon, information about language and the world is distributed in our interactions and representations of the world. For Kuhn, we only access the world from our lexicon. In the same vein, Shapin and Schaffer reinforce the idea that knowledge is social and to be accepted as a product of the collective, it is necessary to use social and literary technologies, such as certain language games (which are social and linguistic), beyond of scientific artifacts themselves, or what they call material

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[13] Kuhn's criticism appears in "The Trouble with the Historical Philosophy of Science" (Kuhn 2000 [1992], 105-120).

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technology. Finally, I remarked that Wittgenstein's influence was a huge presence in Kuhn's analysis as well as in Shapin and Schaffer's book.

In understanding the role of language as presented, in what follows, based on the later Wittgenstein, I will seek to address more specifically the issue of language in the advent of the scientific revolution. The point is not to show historically how a particular scientist – or scientific theory – in the early days of science established scientific knowledge or created a scientific community, but to understand the epistemological – and not precisely historical – process of the scientific knowledge production in that context. Therefore, seeking a possible "origin" of modern science is not about establishing the historical "ground zero" of this event, but about attempting to understand it epistemologically as a mechanism of production of knowledge as such in that context of the emerging capitalist society that led to the scientific revolution. In analogy to Charles Darwin's use of the word "origins", in his *The Origins of Species*, where the celebrated British scientist does not seek to find the "ground zero" of evolution but to understand the mechanism of "speciation" that generates or originates a new species. Thus, I am trying epistemologically to recognize the device that creates a new process of knowledge production that took place between the world of medieval man and that of modern man.

As in Shapin and Schaffer, and partly in Kuhn, the assumption here is that the construction of modern science constituted a new form of life (a lexicon for Kuhn or thought style according to Fleck), specifically, an experimental form of life, as the authors of *Leviathan and the Air-Pump* established, or one could say a scientific form of life. In other words, my goal is to understand, from an epistemological viewpoint, the assumptions of the advent of modern science or how a pre-scientific society starts – from the late Middle Ages – to create the mechanisms to constitute itself as a scientific society. In the authors analyzed above, this question about the epistemological device in the advent of modern science appears partially, since they sought to analyze how science was historically done in its early days and not necessarily how, between the fifteenth and seventeenth centuries, it was structured the mechanism of knowledge production that drove to modern science. In other words, in interpreting the history of science, they highlighted how science worked considering social and linguistic aspects, but they are not necessarily looking for the mechanism that constructed science, in terms similar to those discussed by Zilsel and Koyré, when these authors try to explain what produced the scientific revolution. Therefore, the aim here is to use the linguistic approach – already partially developed by the authors treated above – to answer the question directly about the scientific revolution or the advent of modern science as posed by the internalism versus externalism debate.

According to the Zilsel thesis (Zilsel 2000 [1994], 6), as mentioned earlier, the social and economic conditions brought by capitalism, by presenting new values such as individualism, competition, profit, etc., created an environment that allowed the approximation of practical knowledge of higher craftsmen or artist-engineers to theoretical knowledge of academics philosophers (in addition to humanists). This union of the artisans' practical knowledge to the academics' methodology made possible, according to Zilsel, the construction of modern science. From the Wittgenstein's linguistic viewpoint, we could further argue that this confluence between technical and theoretical knowledge in this society enabled not only social and technological developments (by turning technique into technology), but it also established epistemological developments by generating theories about nature, improved experimental technical apparatus and finally created the science. Unfortunately, however, Zilsel did not stress the importance of language in this process. As a consequence, in the historiography of science, metaphysical theses such as those of Koyré and Burtt became prioritized to explain the scientific revolution.

To understand how language is linked with the Zilsel thesis, we need to look at some developments of this thesis. For this philosopher and historian of science, the new

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production system of capitalism, rather than prioritizing the production of war artifacts, was widely used in the production of varied artifacts and goods consumption, which was unlike other socio-economic contexts, such as in the Roman Empire, for example (Zilsel 2000 [1942], 8-9). This reorientation of the technical output in this new scenario also implied more and more social and economic transformations that gradually changed medieval society. There was significant growth in new techniques that brought about major social implications. If we seek to see the linguistic thesis connect to the Zilsel thesis, one can see that this complexification of techniques in this new social order also presented new pragmatic and linguistic rules that significantly modified the very social structures. In other words, new language games have emerged because these new techniques and their different uses have come to imply the construction not only of new technical devices with their new terminologies but their applications in the newly emerging social settings. In Wittgensteinian terms, it was the establishment of new and varied language games in this emergent form of life, or, as one can say, the constitution of a "grammar of knowledge".

In that environment there were favorable conditions – which possibly rested on imponderable historical constraints – that brought about a new technical knowledge. This development was in opposition to the traditional medieval culture that was hitherto predominant. Although this medieval knowledge was based on traditional practices and customs, it did not have systematic and written methodologies in its formulation and transmission. And, of course, there was not a stimulus for this purpose. Unlike medieval society, in early capitalism, the new techniques were formulated and codified in treatises and manuals with specific terminologies and uses, and could thus be transmitted and reproduced in different places, thereby solving local and cross-border problems. Putting it in another way, these new "technical language games", unlike traditional knowledge, constituted a new grammar of knowledge, specifically, a new set of social, linguistic, and pragmatic rules (grammar) that, more than the technical devices itself, changed the social conditions of its surroundings.

For the author of *Philosophical Investigations*, grammar is this set of rules for the use of words in specific contexts of actions and social interactions, thus being more than mere linguistic rules, rules of behavior.[14] Therefore, for Wittgenstein, the rules that make up our grammar come from our "patterns" of behavior, our habits, customs, and institutions (Wittgenstein 2008 [1953], §§ 142, 199, 202, 226, 227). When we understand the rule as the product of a language game, we can conclude by the operative character of the rule. Following a rule is an operation – this is the pragmatic character of the rule. According to Wittgenstein, grammar is this set of rules, uses, and language games based on a form of life. It is in this sense that, based on these technical and social language games, the modern scientific culture will be constituted. Science will be set up as a new grammar of knowledge or a new form of life, notably, under the social and technological conditions from the XV to XVII centuries, we will find the presuppositions for the constitution of the grammar of the scientific revolution.

To sum up, from the end of the medieval period, the new scenario brought by capitalism made possible a new grammar of behaviors, habits, customs, and institutions in which the new techniques that emerged created new technical language games leading to more and more new social uses for them. In other words, in that context, the more one has the development of new techniques – and later the technology and science in itself – the

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[14] In his *Philosophical Investigations*, Wittgenstein distinguishes two levels of grammar: "surface grammar" (*Oberflachengrammatik*) and "depth grammar" (*Tiefengrammatik*) (Wittgenstein 2008 [1953], § 664). Surface grammar addresses the specific characteristics of expressions without regard to the general grammatical and social context in which these expressions are generated. On the other hand, depth grammar is a grammar in which the rules of language are engendered in its relation to the whole set of social, linguistic, behavioral rules.

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more exponentially one saw the creation of new language games that gradually allowed for the development of institutions and theories necessary for the construction of modern science.

More than producing new techniques impacting society, in this new context, devices were also created to transmit this knowledge. It is a period in which technical manuals proliferate (Rossi 2009 [1962], 37-40). The treatises brought new terminologies, new uses, and new social implications. Finally, new language games were constituted by sponsoring the new social orders – which reciprocally demanded new techniques – that would virtually form modern society. Thus, one can argue, in Wittgensteinian terms, that these new technical language games constituted a new grammar of knowledge. At some point, the traditional epistemological conceptions themselves would be affected by this movement, which would become the basis to creation of modern science – of course, science itself went beyond these technical, social and technological aspects (But the most very high theoretical aspects are also the fruit of the same grammar).

An essential point to understanding the relevance of these new technical language games in the construction of this grammar of knowledge (form of life), which developed from the Renaissance, is the analysis of the issue of technique (art) as *imitatio naturae* (imitation of nature) or the relationship between art and nature. The Renaissance built a new perspective on this issue that could be analyzed, in Wittgensteinian terms, as a new *grammatical consideration (grammatische Betrachtung)* (Wittgenstein 2008 [1953] § 90), or the creation of the new grammar of knowledge. According to the Aristotelian view, in the ancient and medieval world, *techné* (art) or art (*ars*) was conceived as the imitation of nature. It was the "artificial" by imitation of the "natural", particularly, the human constructs as a copy of nature. However, in the Renaissance, with the accumulation of these new techniques, this issue will change completely. The technique will no longer be a copy of nature (Rossi 2009 [1962], 145-152). This process can be understood, according to the grammar of knowledge, as a type of "autonomy of technique" over the simple exercise of imitating nature. Understanding this process of autonomy of technique as a grammatical consideration means that there was a change in the set of rules within the technical language games. These new techniques now serve many social and economic purposes that do not necessarily have as their central assumption the imitation of nature.

Although nature could be the source of inspiration and ultimately the very limits of what can be done, this accumulation of new techniques and their social implications has shown that it is possible to engender these new technical rules (grammar) without being an imitation of nature. These new technical language games, as social devices, had in themselves their own logic and purposes. In other words, it is possible to have rules that copy nature, but also rules that do not imitate nature and yet can have consistency and are capable of expressing and transforming their surroundings with different social modulations. Finally, techniques are not just the imitation of nature, but also the imitation (adequacy) of society. Not all technical and social interaction would need to be based on the Aristotelian postulate of imitation of nature; so it was possible to codify technical processes that had, as their specific purposes, to enable social and linguistic (pragmatic) interactions as an autonomous system, or at least only secondarily so as to keep their references to nature.

From this viewpoint, beyond *imitatio naturae*, the new techniques simulate the social structures that promote them. Like the social, the techniques as products of this society are ruled structures (grammar), thus showing their condition as language games. It is in this sense that technique is constituted as an extension of the social. A rule (technical, social or linguistic) can only have a meaning and therefore be effective if it is inserted within the context of a social praxis. In this sense, a technique is a linguistic and social extension. Indeed, a technical device created by this society only makes sense if it reflects the linguistic and social rules of that society. Any technical object is invested by the grammar of the society

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that created it. Just as grammar is a social product, a technique is also a social product that is governed by the rules of the society that created it. Based on this crucial point, it follows that grammar – as a set of linguistic, social, material and behavioral rules as a whole – establishes a social convention which, by emerging in the "rough ground" (Wittgenstein 2008 [1953] § 107) of these social practices, could be different if this praxis were otherwise (or could be changed from one society or a form of life to another).

Rules make up our grammar come from our "patterns" of behavior, our habits, customs, and institutions (Wittgenstein 2008 [1953], §§ 142, 199, 202, 226, 227). In ancient and medieval societies, the rules for the construction of technical devices were simple because their social demands and the possibilities of their institutions were also simple. These were relatively simple societies. Therefore, there was not a higher degree of social complexity in these contexts, which would allow them to develop their techniques. If the technique reflects the society that created it, then noncomplex societies tend to develop simple techniques, whereas complex societies tend to produce sophisticated techniques. Not only is technique a language that reflects the society that created it, but the language in itself – which orders social and technical processes – that is also a technique. "To understand a language means to be master of a technique" (Wittgenstein 2008 [1953], § 199).

In this sense, language games and grammar are not a type of natural metaphor or *imitatio naturae*. They are not a simulacrum of nature. They are an expression of human action, to be specific, the linguistic metaphor of "grammar", as a set of language games and their rules, hold the idea that language (by its plasticity) is not a simple representation of nature (although it need to place oneself within the limits of nature), but an expression of human creative activity in its interaction with nature.

Therefore, one can conclude that modern science arose when modern society was able to create more and more complex social and technical rules that were not necessarily limited to be a copy of nature. The development of technique allowed us to move from the idea of a "natural man" to an "artificial man". As an artificial being, humans are governed not only by their biological nature (natural being) but by their social behavior. In short, modern science arose because the modern man was able to create new social, technological, and linguistic rules in the new context presented by capitalism, which reached a level of complexity that placed the idea of *imitatio naturae* in the background. In other words, modern science arose when society was able to create complex rules of social behavior and produce a knowledge of the world that was not the mirror of nature (*imitatio naturae*), but rather reproduced by society itself in interaction with its environment. Finally, modern science arose when a new grammar was created with its different and varied language games.

The notion of grammar promotes the understanding of language from a different perspective than the traditional conception of language based on an idea of representation or copy of nature. From the viewpoint of grammar, there is now a social (collective) "interaction" of mankind with nature. This position promotes a breaking of the Aristotelian and Kantian grammar of categorization, thereby establishing a new "grammatical consideration" (Wittgenstein, 2008 [1953] § 90) or a new point of view (*neuen Aspekts*) (Wittgenstein, 1980 [1977], 18). The main point is no longer about building categories, as Kuhn wanted by rehabilitating Kant's ideas, but about "following the rules of the language game" (Wittgenstein 2008 [1953] § 206) in the form of life. Following the rules, allows us to understand the grammar that connects us to the world.

Based on the idea of grammar explained above, we can finally contest Koyré's metaphysical statements about the scientific revolution. As aforementioned, for the Franco-Russian historian of science, since ancient Greece, science is mostly theory and, if technical elements were essential to the scientific revolution, it would have occurred with the Roman engineers a thousand years earlier. According to the grammar of knowledge, one may argue

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that the Romans could not develop science because the technical and social devices at that time would hardly have evolved enough to reach the scientific thought. Roman society did not constitute a form of life developing the technique and its social implications to the point of creating science. Consequently, the Romans failed to produce a scientific or experimental form of life. Modern science arose because modern society was able to create a new social and technological grammar that gave solid foundations to this process. Modern society has reached a high level of complexity in its rules (material, behavioral, and linguistic). These rules (social and technical) did not exist in the Roman empire. Indeed, science is much more than technique or technology having important social, material, and theoretical aspects, – although, ultimately, the theory itself is the product of this grammar of knowledge. However, for grammar and its language games, all these aspects (social, technological, material and theoretical) work together. In this way, one can conceive that the confluence of practical and theoretical knowledge, as pointed out by the Zilsel thesis, brought about the advent of science.

Conclusion

This article sought to demonstrate the importance of language in the construction of modern science, which is called the linguistic thesis about the scientific revolution. It is assumed that language, understood from a pragmatic perspective, provide us with useful elements to understand how the confluence of practical knowledge from the craftsmen and artist-engineers, and the theoretical knowledge of the philosophers – as pointed out by the Zilsel thesis – made possible the advent of modern science. Following its purposes, the article analyzed how the historiography of science worked the problem of language. In the next instance, the pragmatic approach was developed, especially from a Wittgensteinian viewpoint, as an instrument for understanding the scientific revolution. Finally, the article sought to demonstrate that with a linguistic reinforcement of the notion of grammar, the Zilsel thesis is an excellent tool against metaphysical theses about the scientific revolution as defended by historians, such as Koyré or Burtt.

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