

A NEW FORM OF KNOWLEDGE: *EXPERIENTIA LITERATA*

Laura GEORGESCU*

Abstract. In this paper, I assess Francis Bacon's methodological considerations on the process of experimentation in order to show that experiments and experimentation have a productive role in his scientific inquiry. By looking at the structure of the problems selected for investigation, and at the ways they are addressed in the *History of the Winds*, I emphasize some of the epistemic functions of the experimentation process: the generation of new unknown effects, direct and essential contribution to conceptual innovation, the extension of the domain of research, and the pinning down of the essential factors for producing the particular effect/phenomenon that is under study.

Keywords: Francis Bacon, *experientia literata*, *History of the Winds*, experiment, natural history, methodology

Introduction

Is there a logic of discovery? This is one of the guiding questions of Bacon's philosophical program. The widespread belief among both historians of scientific method and historians of the early modern period is that Bacon's answer to this question is the intricate inductive model of the *Novum organum*. For the modern historian of philosophy, the methodological rules making up the first part of the second book of the *Novum organum* are generally considered to be the key to understanding Bacon's logic of natural philosophical discoveries.¹ But *Novum organum* includes also non-inductive methodological elements, like the prerogative instances (Latin: *prerogativis instatiarum*) that were overlooked until the beginning of the 70s when the seminal work of Graham Rees revived Bacon's philosophy of experiment.

These new methodological elements require integration in Bacon's overall view of how knowledge is generated. Thus, if the inductive process seems to allude to a set of rules for avoiding the human mind's tendency to rush to ungrounded conclusions, the prerogative instances refer to ways of generating good experiments (understood as the experiments that are appropriate for dealing with the research question). Although Bacon devoted more than a hundred pages of the *New Organon*

* University of Bucharest, Faculty of Philosophy, Department of Theoretical Philosophy, 204 Splaiul Independenței, București, e-mail: georgescu.laura@gmail.com.

to explain how the twenty-seven types of prerogative instances should be used for natural philosophical purposes, this did not receive much attention. But, briefly put, the prerogative instances refer to types of productive experiments or specific instruments helpful for generating the natural and experimental histories.² The way the natural and experimental histories are generated is an interesting topic for further exploration, but the main theme of this paper relates to another aspect of the composition of such writings, namely the way the empirical data is organized in order to advance and ultimately ground knowledge. Accepting the claim that *experientia literata* is integrating and bounding empirical (experimental) knowledge in Bacon's natural historical writings, in this paper, I will explore its value for the process of knowledge generation.

Bacon's conception of *experientia literata*, and of the ways this technique contributes to the advancement of knowledge, has captured the interest of Bacon scholars and historians of science only recently. The recent discussions over the content and structure of Bacon's natural historical writings were accompanied by assessments of *experientia literata*. As a result of such studies, it has been suggested that *experientia literata* provides the material of the natural and experimental histories.³ How is this done and in what way it contributes to the natural philosophical form of knowledge are still open questions. Probably the earliest study dealing with the place *experientia literata* occupies in Bacon's philosophy is Lisa Jardine's, "*Experientia literata* or *Novum organum*. Bacon's two scientific methods" (1985).⁴ The study suggests that the *experientia literata* technique is Bacon's answer to skeptical worries about data gathering, and that it organizes the materials of the "primary natural history" and extends them to include new otherwise-unrelated instances.⁵ Jardine claims that with the help of *experientia literata* Bacon manages to identify the connections that reflect the nature of the world, rather than the mere constructions of the human mind that pervade the speculative forms of natural philosophy. The important role Jardine attributes to *experientia literata* is also accepted and underlined by Sophie Weeks in "Mechanics in Bacon's Great Instauration."⁶ Weeks stresses the relevance of this device in relation to the following functions: the fact that *experientia literata* helps generate *experimenta lucifera* (experiments of light) that contribute to the discovery of causes; and the fact that *experientia literata* is a help for memory.⁷ The aspect that is of utmost importance for Sophie Weeks' approach, though, is *experientia literata* as a mode of discovery that works by transferring existing inventions or known processes from one mechanical domain to another. Studies such as Jardine's and Weeks' have focused on reconstructing Bacon's view of *experientia literata* and the role it plays by carefully examining Bacon's more methodological texts, leaving aside the actual composition of the natural histories. In opposition to this approach, by working on the deconstruction of the natural historical practice, Dana Jalobeanu has claimed that *experientia literata* is in fact Bacon's answer to the very logic of discovery, and that the

key to unveiling Bacon's view of how knowledge advances comes at the interplay between his matter theory and this art of experimentation.⁸

Pursuing this line of investigation, in the analysis of the *History of the Winds* that follows, I point to some of the epistemic values of the experimentation process. I intend to show that *experientia literata* comprises a set of rules for securing the experimental facts and furthering the inquiry. I will show that a natural historical investigation of the type Bacon constructs in the *History of the Winds* is not about establishing the "final" causal explanation of the phenomenon, but rather about experimentally mapping out the empirical relations and conditions that influence or determine the ways in which the investigated effect is experienced. Such forms of investigation have epistemic priority because they attempt to make intelligible the properties and conditions of occurrence of the investigated effect. The epistemic priority is even more reinforced by the unknown character of some experimental results and by the fact that, at times, such experimental investigation conduces to conceptual innovations that become integrative parts of the local theories (the causal explanations of the studied phenomenon). I have structured my argument as follows: in the first part of the paper I present relevant aspects of Bacon's own theorization of *experientia literata* and I then discuss how it is supposed to work. In the second part, I investigate the topical and experimental structure of the *History of the Winds* in order to show how the experimentation process produces scientific knowledge.

The conceptualization of *experientia literata* and its integration within the Baconian natural and historical program

In book 5 of *De augmentis scientiarum* (1623), Bacon introduces four subdivisions of logic, i.e., the rational arts of "Inquiry or Invention; Art of Examination or Judgment; art of Custody or Memory; and art of Elocution or Tradition."⁹ These rational arts of inquiry are devices helpful in producing (inventing that which is sought), grounding (judging that which is invented), preserving (retaining that which is judged) and transmitting (delivering over that which is retained) knowledge.¹⁰ These rational arts represent the main directions of epistemological investigation for Bacon, and, as he makes evident, while the *art of memory* and the *art of elocution* deal with ways to properly preserve and transmit knowledge, the *arts of invention* and *examination* are directly related to producing knowledge. Bacon seems to believe that a proper method for discovery can be ultimately formulated. If the *art of examination* scrutinizes the nature of proof and demonstration and comprises the analysis of both inductive (in the Baconian sense) and syllogistic (deductive) reasoning,¹¹ the art of inquiry or invention deals with the rules and procedures by which the human mind might hope to obtain systematic knowledge.

The rational art of inquiry is in its turn divided into the art of discovering arguments and the art of discovering "arts" (sciences). The latter is the component

without which knowledge itself is impossible, because it deals with making the intellect “by help of art a match for the nature of things.”¹² Bacon states that such art is not about correcting the human mind, but about finding some rules so as to “urge things which are too subtle for the sense to some effect comprehensible by the sense”¹³ and to avoid the “stumbled upon” type of knowledge (chance discovery) that had previously dominated the physical inquiries.

What a “logic” of scientific discovery is, or whether the dynamic scientific process actually conveys such a well-defined structure, is difficult to say. The rather new discipline that integrates history and philosophy of science has revived the problem of a logic of scientific discovery in the context of an increased interest in analyzing and understanding the scientific process and the processes of theory generation.¹⁴ Yet no widely accepted answers to such questions have been formulated. But, in its minimal sense, presumably, a “logic” of discovery should consist of a set of rules that guide the inquirer’s activity and help him generate what would be considered, in relation with a determinate set of values, reliable knowledge about the world. These minimum requirements can be found in Bacon’s texts. Thus, the art of inventing “arts” (domains of knowledge) had internal methodological rules (rules for good experimentation, for example), some criteria to evaluate the “discoveries” (one such example would be the requirement to manipulate and actually put to use the experimental result¹⁵) and even a general purpose of the quest for knowledge (the restoration of man’s dominion over nature¹⁶).

In this context, it seems safe to assume that Bacon had a particular interest in formulating a “method” for discovery. Yet, the Baconian texts raise a new puzzle. In *De augmentis scientiarum* Bacon proposes a two-fold division of the procedures of discovery: the method presented in the *Novum organum* (*interpretatio naturae*) and *experientia literata*.¹⁷ These two methods work differently: while *interpretatio naturae* proceeds from experiments to axioms and from these axioms to new experiments, *experientia literata* proceeds from one set of experiments to another as if one “may be led by the hand of another, without himself seeing anything” and, in consequence, it never ends with an axiom of nature. Both *experientia literata* and *interpretatio naturae* are parts of the same art. Yet how the two relate, or whether they are related at all, is still a point of argument in the secondary literature¹⁸: it is still unclear if *experientia literata* is Bacon’s alternative to the project of the eliminative induction or part of it. Moreover, in the discussion dedicated to art of invention from book V of *De augmentis*, Bacon clarifies what is to be expected from *experientia literata*, but leaves aside the aspects of the method of the *interpretatio naturae*. We are informed that *experientia literata* technique deals with the process of experimentation and it generates experimentally based forms of knowledge.¹⁹

As it is well known, for Bacon, any attempt at understanding the physical world has to be built around empirical sensorial information. Thus, experience is crucial for any physical investigation. But, in contrast with the more complicated discussion on the nature of experimentation and on the requisites a trial should

fulfill to be considered a good experiment that flourished in the second part of the seventeenth-century, Bacon equates experiment to guided experience. Thus, if experience is organized, systematized and filtered according to a method, those experiences cease to be “mere accidental experiences” and become “experiment.” For Bacon, an experiment is a set of observations and artifact situations that are relevant for the problem or question investigated.²⁰ For example, in *De fluxu et refluxu maris*, while trying to understand whether the motion of the tides is from east to west, Bacon brings forward three instances of some particular historical events labeling them as “experiments.”²¹ Accordingly, Bacon identifies three ways of incorporating the sensory information, all of which are associated with experimental forms of knowledge. The first form of integrating experiments into sciences is the empiric’s way: a process of experimentation that is chaotic, unordered, a kind of “groping in the dark,” that can at most stumble upon a “discovery.”²² The second form of experimentation has two main properties: direction and order “for keeping experience going and advancing it.”²³ This is the way of *experientia literata*, a device that helps the human mind to proceed through experience securely “in accordance with a fixed law, in regular order, and without interruption”²⁴ from one experiment to the other by means of the eight modes of experimentation. The third form of integrating experiments is the product of the interpretation of nature. *De augmentis scientiarum* provides no actual information on how experiments are expected to work. The difference between *experientia literata* and the experimentation of the *interpretatio naturae* resides within an analogy. Thus Bacon states that the integration of experiments in the natural philosophy is comparable to the way a man might try to find his path. Thus, whereas *experientia literata* is akin to a man groping in the dark, guided by the hand, the experiments associated with *interpretatio naturae* are the equivalent of lightning a torch in one’s path. To what extent this analogy is revealing is hard to tell, but it does suggest that with research activities guided by *experientia literata* the researcher is only following the rules of the process and has no anticipation of the experimental results. In case of *interpretatio naturae*, on the other hand, the experimental effect is known and put to test.

Moreover, Bacon states that the biggest difference between these two modes of discovery is the type of knowledge they provide. So, whereas *interpretatio naturae* ends with axioms of a lesser or higher generality that are “certain,” the knowledge obtained as a result of a natural historical activity guided by the procedures of *experientia literata* has a hypothetical and provisional character.²⁵ The discoveries of *experientia literata* are not submitted to questions of truth or certainty, because they just decompose the investigated phenomenon and analyze the factors involved either in its generation or its behaviour modification so as to make it make intelligible. In case of the knowledge obtained as a result of the method of *experientia literata* the grounding of the results is done on basis of the manipulability of the experimental results and their alleged practicability. On the contrary, the method of *interpretatio naturae* seems to be more interested in generating conceptual knowledge.

Moreover, *experientia literata* is the method chosen to explore the natural world and to build up the empirical correlations of things, whereas *interpretatio naturae* builds up the theories explaining the correlations.

This is why Bacon is keen to assert that, rather than a science, *experientia literata* is a process of “hunting by scent,” a kind of sagacity guided by variation, production, translation, inversion, compulsion, application, coupling, and chances of experiments: the eight modes of experimentation.²⁶ By means of these modes of experimentation, the experimental context is varied so as to extend the domain of investigation and generate new “discoveries” relevant for the problem under study. In what follows I shall briefly present what these eight ways of *experientia literata* are and how they are supposed to work. Looking at the way Bacon presents them in *De augmentis* they seem to be the legitimate ways of going from one experiment to another, or from one experimental outcome to another. With their help, the information experimentally obtained is preserved and enchained in one explanatory structure. Moreover, for Bacon these forms of experimentation are a good indicator for how to draw good analogies, or true correlations of nature, that make for a good classificatory scheme (for example, establishing a relation between the optical illusions that one can see in the sky and optical illusions seen around the flame of a candle provides a basis for grouping them together under a common heading).

Variation is the experimental procedure by which specific parameters of the experimental setting are modified. One such parameter can be the *type of object* to which the experimental setting is applied: one observes that grafting is beneficial to fruit-bearing trees and subsequently attempts it in the case of wild trees or flowers (objects with similar properties).²⁷ Another parameter which can be modified without altering the informative value of the experiment is *the efficient cause*. Thus, in order to answer the question of whether stars have the ability to emit heat, Bacon suggests replicating the experiment in which a lens is used to focus the light of the sun in order to light a fire. Immediately after this, Bacon advises that the same procedure be repeated by pointing the magnifying glass towards the Moon. Consequently, a new variation of the objects toward which the magnifying glass would be pointed could provide some insights into the role light plays in this particular investigative context.²⁸ A final type of parameter of the experiment that should be submitted to variation is *quantity*. Bacon proposes that the quantity should be varied in almost any type of experimental setting, as a way to secure the experimental results; especially given his belief that quantity “must be treated with great care, as it is surrounded by many errors.”²⁹

The second mode of experimentation regards the *production of the experiment*, understood either as the iteration or repetition of an experiment, or as the situation in which an experiment is led toward the production of a more subtle effect. The examples Bacon offers (e.g., his experiments with the magnetic needle) indicate that, ultimately, the *production mode* is nothing more than a particular species of variation used to unveil otherwise unknown effects. The *translation* of the experiment can be

of three kinds: from nature to art, from one type of art to another, or from one part of an art to another part of the same art. This type of experimentation implies the artificial imitation of natural phenomena, such as generating artificial rainbows, inventing eyeglasses in order to improve sight, and artificial freezing with salt. It comprises attempts to transmute firmly the information from one domain to another. *Inversion* is the type of experiment applied to the counterpart of a substance or object for which the experiment had been designed initially. This type of experimentation strategy seems to accord with the Baconian theory of matter and the identification of some pairs of opposite cardinal virtues as basic processes: hot–cold, dense–rare, etc. The *compulsion* mode is a form of experimentation that establishes the boundaries of an experimental effect; Bacon’s examples include the limit distances at which magnetism can be experienced, and the actual limits of the magnifying power of looking glass.³⁰ By establishing the limits, the identified relevant factors for the effect’s occurrence are tested. The *application* and *coupling* are modes of experimentation associated with translating the results of a proven useful experiment to another experiment, and thus extending the domain of investigation, further comprising many other effects under the classificatory scheme that the initial experiment has set. *Application* and *coupling* are also associated with simply assessing other previously-obtained experimental results. These tokens of experimentation are constrained to work on non-specifically designed experiments so as to allow for the continuous manipulation of the parameters and thus the extension of the field of natural history.

A set of distinctive features of the *experientia literata* device can be identified: the experiment must not have an intricate design (to permit the constant variation of the parameters); the experimental results are not known beforehand, but because the experiment proceeds through the modes of experimentation the results are considered relevant and objective. All these features are interrelated: it is precisely because the experiment is not designed to test a hypothesis, but to explore a particular problem that the experimental setting can be varied; and the experimental results are taken to be reliable precisely because the law of experimentation is in place. And the novelty of the experimental results is part of what explains the productive role of *experientia literata* and its epistemic character. All these features underline Bacon’s point, according to which the research activity, when dealing with a subtle effect of nature that the human senses and ultimately the human mind cannot grasp, has to deconstruct the effect and make it comprehensible for the human senses. The deconstruction implies the mapping of all the relevant and necessary conditions for the occurrence of the effect investigated, or of the changes observed in its behavior. This is the most valuable function of *experientia literata*. Since it works by systematically varying some conditions or by establishing the appropriate analogies, it helps to map out and dissect the investigated thing and to advance knowledge by establishing empirical regularities (if A under X conditions, then C), and in return to continuously generate new relevant problems. The results

secured by the experimental process become *the 'scientific' facts*.³¹ *Experientia literata* is not a device for constructing the setting of the experiment, or for generating experiments from which to construct natural histories (for Bacon, the methodology that generates an experiment that advances knowledge about the topic under investigation comes in the form of the prerogative instances). Instead, *experientia literata* is a technique that shows the ways in which an experiment can continue to be informative, can produce new tests and new experiments, and can maintain the “experience advancing.”

In the first book of the *Novum organum*, Bacon suggests that *experientia literata* is a technique that should build up the natural and experimental histories, not only because the experiments of the mechanical arts have to be part of the natural histories, but also because “[s]o far mental effort has had a much more important part to play in discovering [*in inueniendo*] than has writing, and indeed experience has yet to be made literate. And no discovery should be sanctioned save that it be put in writing [*Atquinulla nisi de Scripto inuentio probanda est*]. Only when that becomes standard practice, with experience at last becoming literate, should we hope for better things.”³² I take this to point to two things: first that *experientia literata* as a method of discovery is composed of strict rules – the modes of experimentation that must be thoroughly followed in composing the actual natural and experimental history. The rules of *experientia literata* work as a mechanism warranting the advancement of understanding independent of the natural inclinations or abilities of the researcher. And second, that *experientia literata* is also a form of preserving knowledge and that, because it entails an order and a method, it acts also as a ministration of memory. The recording and organization of the activity suggested by the modes of experimentation have to correspond to the order of the composition of the natural histories, and the order of the information thus presented should prepare the empirical data thus obtained for being gathered into tables and theorized upon.

Experientia literata* in the *History of the Winds

Historia Ventorum (*History of the Winds*) was published in 1622 as the first part of the *Historia naturalis*, the third division of the *Instauratio magna* in a volume entitled “*Historia naturalis et experimentalis ad condemnandam Philosophiam: sive Phaenomena universi*.” The history is composed in accordance with the short text of the “Rules of present history,” and it includes entries such as the articles of inquiry – topics of interest that the natural historian has to study; interspersed “admonitions and cautions concerning the fallacies of things, and the errors and scruples which may occur in inquiry and discovery;”³³ directions for how one can construct *experiments of light* and *instances of special powers* (*prerogative*); and provisional rules helpful in advancing the inquiry.

The natural history of the winds is constructed around a list of thirty-three articles of inquiry into the nature and properties of the wind. Yet, in the exposition,

not all questions get to be fully addressed, indicating the open character of the history. The type of questions Bacon proposes suggests not only the variable character of the subject under investigation, but also the exploratory character of the Baconian natural histories. Moreover, to facilitate and direct the investigation, the topics are grouped into several categories: the classification of winds (articles 1–10), the *confaciens* of the winds (11–15), the limits of the winds (16–18), their succession (19–21), motions (2–27), the force or powers of the winds and their qualities (articles 7, 28–31). The next article of inquiry presents some modalities to make some prognostics of the winds possible, while the final one investigating the possibility of imitating the winds. These categories suggest that such forms of investigation attempt to understand the phenomenon by establishing all the relevant factors that contribute to the observable modifications of the behavior and properties of the winds, and by providing a classificatory system of the relations identified.

When addressing the question of the classification of the winds, Bacon proposes two categories of classification, after the names of the winds and their species. He identifies four types of species in relation to their cyclicity: general – winds that blow always; periodical – winds that blow at particular times; attendant – winds that blow more frequently; and free winds.³⁴ Of the four identified species the one that is of utmost importance for Bacon is the species of the general winds – in particular, the wind that blows from east to west in the tropics, because in Bacon’s cosmology the heavens are moving from east to west around a central fixed Earth, as suggested in *Thema coeli* (1612).³⁵ One of the problems raised by the investigation of the heavens is whether this motion is particular only to the heavens, or whether it also pertains to earth and earthy things. This question is reassessed in relation to the motion of the sea in *De fluxu et refluxu maris*, where it is established that the motion of the waters is regular and from east to west, and from this inferred that the diurnal motion of the heavens is also found at the sub-lunar level. In the same context, the problem of a general wind blowing from east to west is addressed. Bacon’s major point is that if one can find a general wind that blows weakly but permanently from east to west, then, by an analogical leap, it can be maintained that the diurnal motion is also a property of terrestrial phenomena.³⁶ Its presence would be further proof that the lower and upper regions display the same behavior and that there is no division between the sublunary and the celestial sphere. The problem of the general winds has two components: whether the general wind blowing from east to west exists and, if it does, what its cause is. In itself, the inquiry looks like a draft rather than a complete and coherent explanation.

On the question of the existence of this type of basic general and universal wind, Bacon gives two instances in support of its existence: the manifestation of a continuous *Brixæ* at the tropics, and the movement of higher clouds from east to west in calm nights. He also identifies a more problematic instance: the difficulty with which the wind can be observed on the European continent. In order to test

the presence of the general wind on the continent he suggests an experiment involving an indirect phenomenon: in situation of perfect calm, when no other particular wind interferes with the general wind, to test whether the weathercocks and wind vanes point to the west. The narrative provides no indication of whether such an experiment is even possible. On the question of its cause, Bacon suggests two possible answers: the general wind from east to west can be caused either because the heat of the Sun expands the air, or because the airy terrestrial motion is part of the universal motion. For coherency with his cosmological system, the cause of the general wind blowing from east to west (the Brize) should have been presupposed to be the latter. Instead, in order to push the investigation further Bacon suggests appealing to an experiment that would play the role of a Crucial Instance so as to establish whether the Brize is felt at night when the heat of the Sun cease.

Crucial Instances are usually read by Baconian scholars as tests deciding which of two alternative hypotheses is confirmed. For such a reading, the fact that the Brize will blow at night is both a clear refutation of the hypothesis of the overheating of the air and a confirmation of a uniform and continuous motion from East to West. However, in Bacon's explanation of Crucial Instances, in the *Novum organum*, they are not exclusively related to evidence – they are not confirmatory instances. A Crucial Instance can be useful in rejecting some of the arguments of the alternative theories, but it does not stand as a confirmatory instance.³⁷ Moreover, although the actual design of the experiment is not specified, the exposition of the natural history seems to suggest a negative result: “but it is certain that this Brize does not blow in the night but that it blows in the morning and even some time after sunrise.”³⁸ Such crucial instances, as the text itself suggests, do not end the inquiry but further it. In fact the very provisional and open character of the natural historical data announces to the modern reader that, for Bacon, the empirical data could not have been used as evidence for the confirmation of any theory. Multiple and varied types of instances that are brought into the natural history as evidence of cases compatible with a particular hypothesis increase the likelihood of the adequacy of the hypothesis, but never act as confirmatory instances. More importantly, empirical data is taken to be productive for the inquiry if it opens new avenues of research or offers new directions for exploring the physical process or phenomenon investigated.

The classification of winds according to the species allows one to observe the birth of a new concept: the attendant winds – winds that blow in all but one part of a country, with a “contrary wind” blowing in the remaining part. With this new concept, Bacon also generates a new map of winds. The new system of classification will be integrated not only in making the phenomenon coherent, but also in constructing a local theory explaining it. Such conceptual innovation is not a unique event throughout the exposition of the history. When discussing the local origin of the periodical winds, Bacon identifies three: from the hollows of the earth³⁹; from

the middle region of the earth before or after the collection of vapours into clouds⁴⁰; or from the expansion or contraction of the air. Bacon lists a series of observations derived from Gilbert, Acosta and Pliny, supporting the hypotheses that winds can originate both from the air and from above. The third source, of the body of the air, is Bacon's own conception of the generation of winds.⁴¹ The explanation is based on an experimental fact already addressed in other Baconian texts (*Phenomena universi, Historia densi et rari, Novum organum*), according to which a quantity of water transforms into a much bigger quantity of air. The conversion of water into air overcharges the air and produces "disturbances on the way," and thus winds.⁴²

The next topic of the history is the naturalization of some "extraordinary and prodigious winds, as fiery winds, whirlwinds and hurricanes,"⁴³ followed by a set of questions intended to establish the empirical conditions (the factors celestial or terrestrial) that contribute to exciting or calming the wind: meteors, earthquakes, rain showers as celestial factors; and soil conditions, melting of the snow, and so on, as terrestrial factors. Such inquiry is interested in investigating what types of other natural phenomena are relevant for determining the properties and the qualities of the particular species of wind. The result is not supposed to be a complete causal explanation, but a more detailed map of the phenomenon. Thus, although Bacon acknowledges that "every impulse of the air is a wind," establishing why this effect is experienced in so many different ways implies establishing the particular necessary and sufficient conditions for the occurrence of a particular effect. Only when the empirical correlations are established will the predictions become a possibility.

A large part of the study of the winds is devoted to the study of some aspects of the motions of the winds. Bacon submits to exploration a series of observable properties of the motion: the factors that increase or decrease the motion of the wind, the direction of the motion, the longitude of the motion, and its undulation.⁴⁴ In order to study the motion of the wind, Bacon appeals, along with particular historical events, to an experiment that was initially designed to study the generation of the winds: the tower experiment. This experiment is an analogical reconstruction of the effect that the sun's heat has on the air. What Bacon proposes is a simple and ingenious experimental setting: in a round, shut tower, a bunch of "thoroughly ignited" coals are placed in the middle of the room. At one side of the tower, a thread with some feathers is suspended. Since the air is dilated as a result of the heating, Bacon observes that the feathers are permeated with an oscillatory motion.⁴⁵ In order to better grasp what is happening, the experimental conditions are adjusted: a hole in the tower's window allows Bacon to observe a new unexpected effect – the fact that the direction of the motion of the feathers is continuous, "intermittent, and in undulating currents."⁴⁶

By multiple variations of the experimental setting, Bacon concludes that overcharging the air can produce winds. He now uses the experiment that was initially designed to understand the effects of heat in relation to the generation of winds in a new context: in order to explore the motion of the winds. Thus, by

replacing the hot coals with a kettle of boiling water, not only is it established that vapours contribute to the formation of winds, but it is also observed that the feathers moved more slowly, because the “heat was not strong enough to prevent the dewy vapour of the water from hanging in the air, and could not dissipate it into the matter of wind.”⁴⁷ Another variant of his explanation of the efficient cause combines the effects of the coals with those of the boiling water, observing that the motion of the feathers is increased, “so that it appears sometimes to be lifted up as by a small whirlwind.” Thus, the experiment is transferred from one problem to another, and different aspects of the experimental setting illuminate different aspects of the phenomenon investigated. It is to be observed that many of the effects that the experiment brought about (the undulating motion of the feathers, the slow motion of the feathers under the action of the water vapours) were unexpected and became evident only as a result of the process of experimentation. Thus it is not the experiment *per se* as an exclusive discrete event contributing to increasing the understanding of the phenomenon, but the process of variation and manipulation of the experimental parameters – what Bacon terms *experientia literata* – that plays the productive role in the inquiry.

Beyond studying the properties of the motion of the air, Bacon also proposes an investigation of how the wind’s motion manifests itself in machines, especially sails and windmills. The study of the motion of the windmills is nothing other than one experimental set-up varied in different ways. The main rationale behind the experiment is Bacon’s attempt to understand how the speed of rotation of the windmills could be increased. The experiment attempts to test the motion of the windmills by simulating the effect. The technique used (according to the modes of experimentation that *experientia literata* comprises) is the translation of one art (the motion of the windmills) into another art, by analogizing from the motion of the windmills to the motion of the paper sails. Bacon does not generally address the question of whether the analogy is legitimate or not, but along with the technique of translation of the *experientia literata* heuristic, the doctrines of the ontological dissolution of the natural and artificial⁴⁸ and the doctrine of the unity of the motions of matter support the extension/translation of the experimental results from one situation to another. In order to recreate the motion of the windmills, Bacon proposes as instruments some paper sails to model the sails of the windmills, and a pair of bellows to simulate the wind’s motion. Stipulating that the reason for the way the wings move is the very interaction of the air particles with the inclined surface of the sails, Bacon tries to understand which environmental factor is decisive for the speed of the motion. The way to solve the problem is by varying some parameters of the experimental setting. The first attempt is to change the shape of the surface of the wing by adding a fold in the direction opposite to that of the wind. This variation has the reverse effect: it reduces the speed of rotation. Although a negative result, such variation has a positive effect for the understanding: in this way, one can know that the percussion of the wind has to be

in fact increased and not undermined. This situation shows in a simple way how experiments are in fact necessary for rendering some effects of nature intelligible. Besides the emphasis on using some experimental results for practical applications, this experiment has also a more fundamental role: unveiling what types of factors influence or determine the type of motion we see in windmills, and in return opening new directions of inquiry into problems related to the motions of the winds.

In the next context of experimental variation, Bacon places a series of obstacles behind the wings, thinking that by compressing the wind more, the wind will strike with greater force. The effect is once again negative since the “repercussion” is absorbed the initial motion. Bacon decides to introduce the negative results into the narrative not only to point out the limitations of the experiment itself, but also because he holds the conviction that negative experimental results have an instructive role and further the inquiry. The way Bacon understands what is instructive is different from the way Aristotelian science assesses experiments. For an Aristotelian the experiments teach by exposition, by showing how things are; the researcher is an authoritative figure who leads the way and shows, with the help of instruments, how things are. The Aristotelian experiment *demonstrates*.⁴⁹ In contrast, for Bacon, the experiment has a different kind of “pedagogical” role: it gives one the opportunity to explore, to research, to find out for oneself how things might cohere. What secures the experimental result and makes possible the replication of the experimental process is its reliance on the eight modes of experimentation and the natural historical exposition.

In a last attempt presented in the narrative of the experiment of the windmill, Bacon uses another form of variation: the increase of the surface of the wings, so as to make the lateral impact stronger by intensifying the compression of the air. Thus, by translating a natural occurrence into an artificial setting and by using some variations of the experimental setting (precisely the techniques of *experientia literata*), Bacon manages to isolate the decisive factor needed for increasing the speed of the wings: their surface area. In fact, it is also by means of another technique of *experientia literata* (the production of a more subtle effect) that Bacon suggests how this enquiry should proceed. As such, he claims that another relevant factor besides the width of the wings might be the number of wings. Therefore, from an epistemic point of view, with such experiments Bacon proposes to establish both the accidental, irrelevant, environmental factors and the necessary conditions for the phenomenon to occur. This example shows that the experimental variations are used for solving specific problems, such as the rotation of the wings and how to control it, or for establishing, along with the already stipulated cause, the environmental conditions that bring about the phenomenon.

The *History of the Winds* has not received much attention among Baconian scholars. In line with other of Bacon’s natural histories, it appears to be fragmentary and to a certain extent unnecessary. Its value it is not in its content but in the ways

in which the techniques for constructing good natural histories, and the device of the good experimentation, *experientia literata*, intertwine to generate valuable natural historical data in the form of experimental facts. That *experientia literata* is the technique constructing the data of the natural histories explains their probationary and non-doctrinal (non-theoretical) character. Yet this does not mean that the natural histories are not valuable forms of knowledge. As shown above, the rule-based process of experimentation that Bacon proposes may not be enough to generate a final causal explanation, but it instead generates an open-ended inquiry. With the help of the modes of experimentation, it connects dissimilar empirical events, maps out properties and specific patterns of the investigated phenomena, and renders the natural historical information productive for new practical results.

Conclusion

This paper investigated Bacon's proposal for an art of good experimentation, *experientia literata*, by exposing some of the ways in which experiments were included in the *History of the Winds*. By doing so, I unveiled the ways in which *experientia literata* is valuable and integral to the natural historical investigation. It has been shown that *experientia literata* techniques address a more basic but still productive stage of inquiry that deals with mapping out the physical process or phenomenon investigated, without attempting to provide a causal explanation. It was pointed out that *experientia literata* is at least one of Bacon's answers to the problem of discovery, because it encompasses a set of rules for organizing and advancing experience. Moreover, the following epistemic functions have been associated with the procedure of *experientia literata* throughout the paper: the delineation of the essential factors for the phenomenon's occurrence and thus the identification of the relations of dependency; the generation of previously unknown effects which result in conceptual innovations that might sometimes even contribute to local explanations of some properties or behavior of the process investigated; and the extension of the domain of investigation through the inclusion of otherwise disconnected phenomena and the establishment of empirical regularities.

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- ² Rees, G., "Introduction: the *Novum organum* in Context", in *Oxford Francis Bacon*, eds. G. Rees & L. Jardine (New York: Oxford University Press, 2004), lxxvii–xcii (hereafter OFB).
- ³ Jardine, L., "*Experientia Literata* or *Novum Organum*? The Dilemma of Bacon's Scientific Method", in *Francis Bacon's Legacy of Texts*, ed. W. A. Sessions (New York, 1990), 47–67;

Weeks, S., “The Role of Mechanics in Francis Bacon’s ‘Great Instauration’” in *Philosophies of Technology: Francis Bacon and his Contemporaries*, eds. C. Zittel, G. Engel, R. Nanni and N. C. Karafyllis, *Intersections 11* (2008), Brill, 2 vols., vol.1, 133–197.

⁴ Jardine, L., (1985), 133-157.

⁵ Jardine, L., *Francis Bacon: Discovery and the Art of Discourse*, (London: Cambridge University Press, 1974), 143–149.

⁶ Weeks, S., (2008), vol. 1, 133–197.

⁷ An interesting perspective on *experientia literata* as a mnemonic device can be found in: Lewis, R., “A Kind of Sagacity, the *Ars Memoriae* and the Pursuit of Natural Knowledge”, *Intellectual History Review* 19 (2009), 155–175.

⁸ Jalobeanu, D., “The Philosophy of Francis Bacon’s Natural history: A Research Program”, *Studii de Știință și Cultură* 4 (2010), 18–37; Jalobeanu, D., “*Learned Experience* and Constructed Facts: Pedagogical and Therapeutic Aspects of Francis Bacon’s Natural History”, paper presented at the NEC Seminar Bucharest, Romania, March, 2010.

⁹ Bacon, F., Translation of *De augmentis scientiarum*, SEH IV, 407.

¹⁰ Bacon, F., Translation of *De augmentis scientiarum*, SEH IV, 407.

¹¹ Bacon, F., Translation of *De augmentis scientiarum*, SEH IV, 428.

¹² Bacon, F., Translation of *De augmentis scientiarum*, SEH IV, 412.

¹³ Bacon, F., Translation of *De augmentis scientiarum*, SEH IV, 412.

¹⁴ For studies related to current problems and aspects of the “logic” of scientific discovery, see: J. Schickore & F. Steinle, eds., *Revisiting Discovery and Justification. Historical and Philosophical Perspectives on the Context Distinction in Archimedes. New studies in the History and Philosophy of Science and Technology*, vol. 14 (Dordrecht: Springer, 2006); J. Meheus & T. Nickles, eds., *Models of Discovery and Creativity*, (Dordrecht: Springer, 2009).

¹⁵ It should be noted that, for Francis Bacon, physics is not so much related to studying the truth value of the physical statements or theories presented. As he makes clear at many points, the ultimate criterion for judging the reliability of theories is the operation criterion: the ability to generate new technological products on basis of the concepts or empirical connections discovered. In *De augmentis scientiarum* Bacon states: “in Physics, where the point is not to master an adversary in argument, but to command nature in operation, truth slips wholly out of hands, because the subtlety of nature is so much greater than the subtlety of words,” Bacon, F., Translation of *De augmentis scientiarum*, SEH IV, 411.

¹⁶ Regardless of whether Bacon believed in it or just used it as a legitimizing factor, the doctrine of the restoration of the dominion of man pervades the Baconian natural philosophical texts. For the relevance of the quest to restore the dominion of man, see Milner, B., “Francis Bacon: The Theological Foundations of Valerius Terminus”, *Journal of the History of Ideas* 58 (1997), 245–264; Harrison, P., *The Fall of Man and the Foundations of Science* (Cambridge: Cambridge University Press, 2007); Briggs, J. C., “Bacon’s Science and Religion”, in *Cambridge Companion to Bacon*, ed. M. Peltonen (Cambridge: Cambridge University Press, 2006), 172–199; Matthews, S., *Theology and Science in the Thought of Francis Bacon* (Ashgate: England, 2008).

¹⁷ Bacon, F., Translation of *De augmentis scientiarum*, SEH IV, 413.

¹⁸ The relation between *experientia literata* and *interpretatio naturae* is fairly unclear. In the secondary literature, though, some positions can be identified. Thus, whereas Lisa Jardine sees them as two distinct methods, Sophie Weeks opposes exactly this point and suggests

that *experientia literata* is just a stage of *interpretatio naturae*. On this theme, see Jardine, L., (1974, 1990); Weeks, S., (2008).

¹⁹ Bacon, F., Translation of *De augmentis scientiarum*, SEH IV, 413.

²⁰ It is highly debatable whether one can apply the contemporary hypothetico-deductive model to Bacon. Recently, this model was also challenged in contemporary philosophy of science. See Radder, H., "Toward a More Developed Philosophy of Scientific Experimentation", in *The Philosophy of Scientific Experimentation*, ed. H. Radder (Pittsburg: Pittsburg University Press, 2003), 1–19; Buchwald, J. Z., "Descartes's Experimental Journey Past the Prism and Through the Invisible World to the Rainbow", *Annals of Science* 65 (2008), 1–46; Steinle, F., "Experiments in History and Philosophy of Science", *Perspectives on Science* 10 (2002), 408–432.

²¹ The Latin version uses the concept of "experimentum" in all those instances. One such instance is the following: "the tide at the mouth of the Straits of Gibraltar comes in at a certain hour, it is plain that it must come later at Cape Sf. Vincent than at the Straits; later at Cape Finisterre than at Cape St. Vincent; later at Ile de Re than at Cape Finisterre; later at Noirmoutier than at Ile de Re; later at the north of the English Channel than at Noirmoutier; later on the Coast of Normandy than at the entrance of the Channel. And so far it is regular; but at Gravelines the order is completely changed (and that with a great leap), the tide coming in at the same time as the mouth of the Straits of Gibraltar. And this second experiment I refer to the first." Bacon, F., *On the Ebb and Flow of the Sea*, SEH V, 452.

²² For Bacon, inventions as gunpowder or the magnetic needle are chance types of inventions. What is of most relevance here is the tight relation between discovery, invention and technology that Bacon addresses. The usual division between these otherwise different processes is blurred, and the technological criterion seems to be essential not only for bettering human life, but for defining a type of knowledge and its particular properties. Bacon, F., *New Organon*, OFB XI, 169.

²³ Bacon, F., *New Organon*, OFB XI, 159.

²⁴ Bacon, F., *New Organon*, SEH IV, 95.

²⁵ The natural histories that Bacon wrote end with a list of provisional rules indicating the temporary and revisable character of natural historical knowledge. See Bacon, F., *History of Life and Death*, SEH V, 320–335; Bacon, F., *History of the Winds*, SEH V, 196–198.

²⁶ Bacon, F., Translation of *De augmentis scientiarum*, SEH IV, 413–421.

²⁷ Bacon, F., Translation of *De augmentis scientiarum*, SEH IV, 414.

²⁸ Bacon, F., Translation of *De augmentis scientiarum*, SEH IV, 414.

²⁹ Bacon, F., Translation of *De augmentis scientiarum*, SEH IV, 414.

³⁰ Bacon, F., Translation of *De augmentis scientiarum*, SEH IV, 416.

³¹ For discussions of the concept of fact in the seventeenth century, see Dear, D., "Miracles, Experiments and the Ordinary Course of Nature", *Isis* 81 (1990), 663–683; Daston, L., "Baconian Facts, Academic Civility, and the Prehistory of Objectivity", *Annals of scholarship* 8 (1991), 337–364; Poovey, M., *A History of the Modern Fact: Problems of Knowledge in the Sciences of Wealth and Society* (London: University of Chicago Press, 1998); Shapiro, B., *A Culture of Fact: England 1550–1720* (New York: Cornell University Press, 2000).

³² Bacon, F., *New Organon*, OFB XI, 159.

³³ Bacon, F., *The Rule of the Present History*, SEH V, 136.

³⁴ Bacon, F., *History of the Winds* SEH V, 145–159.

³⁵ “[H]eaven revolves in a diurnal motion, the measure whereof is the space of twenty four hours or thereabouts, the direction from the east to west,” Bacon, F., *Theory of the heaven*, SEH V, 551.

³⁶ A schematic analysis can be found in Rees, G., “Francis Bacon’s Semi-Paracelsian Cosmology”, *Ambix* 22 (1975), 161–173.

³⁷ Bacon, F., *New Organon II*, SEH IV, 180.

³⁸ Bacon, F., *History of the Winds*, SEH V, 148.

³⁹ Bacon, F., *History of the Winds*, SEH V, 160–162.

⁴⁰ Bacon, F., *History of the Winds*, SEH V, 162–163.

⁴¹ For an explanation of Bacon’s theory of the origin of the wind and its relation with the experiment of vaporizing water, see Rees, G. (2004), xl–xli.

⁴² Bacon, F., *History of the Winds*, SEH V, 163–164.

⁴³ For more on naturalizing phenomenon, see Jalobeanu, D., “Natural History and *Medicina Mentis*: The Therapeutic Value of Experimentation in Bacon’s Late Works”, paper presented at Warburg Institute in January 2011; Daston, L. and Park, K., *Wonders and the Order of Nature, 1150–1750* (New York: Zone Books, 1998).

⁴⁴ Daston, L. and Park, K., (1998), 175–7.

⁴⁵ Daston, L. and Park, K., (1998), 169.

⁴⁶ Bacon, F., *History of the Winds*, SEH V, 169.

⁴⁷ Daston, L. and Park, K., (1998), 175.

⁴⁸ The Baconian problem of the relation between natural and artificial, its grounds and its effect on his natural philosophical system have been widely discussed and many aspects of the problem are still under constant revision. On this subject, see Newman, W. R., *Promethean Ambitions: Alchemy and the Quest to Perfect Nature* (Chicago: The University of Chicago Press, 2004), 256–71; Rossi, P., *Francis Bacon: From Magic to Science*, trans. S. Rabinovich (London: Routledge and Kegan Paul, 1968), 26–27; Weeks, S., “Francis Bacon and the Art–Nature Distinction”, *Ambix* 2 (2007), 101–129.

⁴⁹ For a more clear account on what the Aristotelian pedagogical role of experiments refers to and how it differs from the Baconian one, see Kuhn, T., *The Essential Tension*, (Chicago: Chicago University Press: 1997), 49; Tiles, J.E., “Experiment as Intervention”, *The British Journal for the Philosophy of Science* 46 (1993); 463–475.