Studies in History and Philosophy of Science 56 (2016) 52–61

Contents lists available at ScienceDirect

Studies in History and Philosophy of Science

journal homepage: www.elsevier.com/locate/shpsa

Experiment and speculation in seventeenth-century Italy: The case of Geminiano Montanari

Alberto Vanzo

Department of Philosophy, Social Sciences Building, University of Warwick, Coventry CV4 7AL, United Kingdom

ARTICLE INFO

Article history:
Received 29 July 2015
Received in revised form
24 October 2015
Available online xxx

Keywords:
Corpuscularism;
Experiment;
Experimental philosophy;
Mechanical philosophy;
Geminiano Montanari;
Natural philosophy

ABSTRACT

This paper reconstructs the natural philosophical method of Geminiano Montanari, one of the most prominent Italian natural philosophers of the late seventeenth century. Montanari's views are used as a case study to assess recent claims concerning early modern experimental philosophy. Having presented the distinctive tenets of seventeenth-century experimental philosophers, I argue that Montanari adheres to them explicitly, thoroughly, and consistently. The study of Montanari's views supports three claims. First, experimental philosophy was not an exclusively British phenomenon. Second, in spite of some portrayals of experimental philosophy as an 'atheoretical' or 'purely descriptive' enterprise, experimental philosophers could consistently endorse a variety of natural philosophical explanations and postulate theoretical entities. Third, experimental philosophy and mechanical philosophy were not, as such, antagonistic. They could be consistently combined in a single philosophical enterprise.

Several recent studies on early modern natural philosophy have charted the origins and fortunes of a movement formed by self-professed experimental philosophers, from Robert Boyle (Chalmers, 2012) and John Locke (Anstey, 2011) to Irish and Scottish societies (Gomez, 2012; Hemmens, 2015). While a number of broad claims have been made concerning this movement, there are few detailed case studies that may enable scholars to thoroughly test those claims (esp. Anstey, 2004; Dear, 1990; Malet, 2013). This paper provides one such case study. It reconstructs the natural philosophical method of Geminiano Montanari. Not only was he one of the most prominent natural philosophers in late seventeenth-century Italy,[1] but also, he discussed the method of natural philosophy in more detail than most of his peers. On the basis of my reconstruction, I assess two claims concerning early modern experimental philosophy. They are the claims that experimental philosophy was mostly a British phenomenon (e.g. Dear, 1990, p. 663; Henry, 2008, p. 55) and that experimental philosophy and mechanical philosophy were, as such, 'antagonistic' natural philosophical views (Gaukroger, 2006, p. 254; see Chalmers, 2012, p. 551).

Having presented the distinctive views of seventeenth-century experimental philosophers (Section 1), I argue that Montanari adheres to them explicitly, thoroughly (Section 2), and consistently (Section 3). This shows that experimental philosophy was not an exclusively British phenomenon. It also shows that, in spite of some portrayals of experimental philosophy as an 'atheoretical'[2] or 'purely descriptive'[3] enterprise, experimental philosophers could consistently endorse a variety of explanations and postulate unobserved, theoretical entities. I then argue that, in several of his works, Montanari tightly integrates his commitments to experimental and mechanical philosophy (Section 4). Most notably, he provides mechanistic explanations within the methodological

E-mail address: alberto.vanzo@email.it.

[1] For an overview of Montanari's natural philosophical activity, see Heilbron (2010, pp. 34-45). For a detailed discussion, see Rotta (1971).

[2] See Boschiero (2007, pp. 70, 137, 247) on 'atheoretical experimental science', 'atheoretical experimental philosophy', 'atheoretical experimental method'. Boschiero's claim that the Cimento academicians were not substantively committed to experimental philosophy is premised on the view that it was 'atheoretical'.

[3] Cavazza (1998).

http://dx.doi.org/10.1016/j.shpsa.2015.11.001

framework of experimental philosophy. This demonstrates that experimental and mechanical philosophy were not, as such, antagonistic. They could be and, in Montanari's case, were combined in a single philosophical enterprise.

1. Experimental natural philosophy

Experimental natural philosophy emerged in England in the 1660s among authors associated with the early Royal Society (Anstey, 2005, pp. 216-220). Seventeenth-century experimental philosophers shared at least three features.[4] First, they employed a distinctive rhetoric, centred around the praise of experiments and observations and the criticism of speculation, that is, of the endorsement of natural philosophical systems without sufficient empirical evidence.

Second, experimental philosophers had common heroes and foes. They praised 'the *Illustrious* Mr. *Boyle*' (Glanvill, 1668, p. 92) and 'the *Immortal* Lord *Bacon*' (p. 72; see Sprat, 1667, p. 35), whom they posthumously recruited as 'the patriarck of experimental philosophy' (Power, 1664, p. 82). They criticized Aristotle, Epicurus, the Scholastics and, especially from the 1680s onward, Descartes for developing natural philosophical theories '*rashly*', without first carrying out extensive empirical inquiries to gather '*due information* from *particulars*' (see Boyle, 2008 [1666], p. 2; Glanvill, 1668, p. 87).

Third, experimental philosophers advocated the employment of a specific method for gaining knowledge of the natural world. It can be summarised in five points, which I illustrate in some detail in this section. In the next section, I use them as a yardstick to determine Montanari's stance toward experimental philosophy.

Negatively, experimental philosophers recommended that:

[E1] one should not firmly commit oneself to any substantive claims or theories on the natural world, unless they are warranted by extensive experiments and observations.[5]

Substantive claims are claims that, assuming the analytic/synthetic distinction is tenable, are expressed by synthetic statements.[6] Accordingly, experimental philosophers decried 'the *espousal* of any' substantive '*Hypothesis*', system, or principle 'not sufficiently grounded and confirm'd by *Experiments*' or observations (Hooke, 1665, sig. A4; Dunton, 1692, pp. vi-vii). They described this as the way of proceeding of speculative philosophers, as the adversaries of experimental philosophy were often called (Boyle, 1999 [1662], p. 12; Hooke, 1665, sig. a3, b1; Sprat, 1667, p. 341).

An implication of [E1] is that experimental philosophers were bound to reject arguments from tradition and authority, as well as a priori arguments for substantive claims—for instance, the a priori arguments that Descartes used in the *Principles of Philosophy* to deny the existence of empty space and to establish the principle of conservation of motion.[7] Hence, the distinction between experimental philosophers and their opponents does not map onto the distinction between philosophers who relied on tradition and authority and natural philosophical *novatores*. Descartes was a *novator*, but he was not an experimental philosopher, even though he often relied on experiments.

Another implication of [E1] concerns the attitudes of experimental philosophers toward substantive claims, theories, and explanations. Despite the anti-theoretical proclamations of some propagandists (e.g. Glanvill, 1668, p. 89), neither [E1], nor the other distinctive views of experimental philosophers entailed that one should not *learn* natural philosophical theories and explanations before carrying out experiments and observations, *test* them, or use them as *heuristic tools* to devise new experiments and observations. Robert Boyle, Robert Hooke, and Thomas Sprat all encouraged these activities. In their view, 'the knowledg of differing Theorys, may admonish a man to observe divers such Circumstances in an Experiment as otherwise 'tis like he would not heed' (Boyle, 2001, vol. 3, p. 171). It may allow one to look for facts which may 'prove' or 'invalidate' theories.[8] It makes 'the Mind […] much more prompt at making Queries', 'discovering and searching into the true Reason of things' (see Hooke, 1705a, p. 19; see Boyle, 2008 [1666], p. 2). Experimental philosophy also allows for the possibility to make a provisional, weak, or tentative commitment to substantive claims and theories before carrying out experiments and observations. Among others, Sprat (1667, pp. 107-108) explicitly allowed this and Boyle (1999 [1661], p. 14) stressed the provisional or tentative status of such commitments.[9] Experimental philosophy only prohibits one to make a strong or firm commitment to claims and theories before carrying out extensive experiments and observations.

Positively, experimental philosophers recommended that:

[E2] In order to make a firm commitment to substantive claims and theories on the natural world, one should follow a two-stage process. During the first stage, one should gather an extensive collection of empirical information by means of experiments and observations. Once this is done, one will be entitled to commit oneself firmly to substantive claims or theories (Hooke, 1705a, p. 18), but only insofar as they are warranted by experiments and observations (Boyle, 1999 [1662], p. 12; Sprat, 1667, p. 107).

[E3] Empirical information should be collected by means of first-person experiences, understood as individual, discrete observations or experiments, which have primacy over theories (Locke, 1975 [1690], II. i. 10). First-person experiences are preferable to reports of others' experiences, that must be carefully evaluated and, where possible, replicated (Hooke, 1726 [1692], pp. 263-264).

[E4] Empirical information should be organized in experimental natural histories (Oldroyd, 1987, pp. 151-152). These differ from traditional natural histories in three respects:

(1) They are not limited to biological kinds. They encompass inanimate beings (air, mineral waters), diseases, qualities or states of matter (cold, fluidity, or density), and the arts.[10]
(2) They include experiments alongside observations.
(3) Their compilation is not a self-standing enterprise, but a preliminary step to the construction of 'a Solid and Useful Philosophy'.[11]

[4] Eighteenth-century experimental philosophers shared most, but not all of these features. For instance, many of them were not interested in experimental natural histories (point [E4]). This paper's statements on experimental philosophy are intended to apply only to seventeenth-century authors.

[5] See, e.g., Robert Moray's manuscript quoted in Hunter (1995, p. 173).

[6] Experimental philosophers could make analytic claims, such as 'all bodies are extended', and rely on them in their arguments. They could also make substantive methodological claims a priori, such as claims on the virtues of good theories, as distinct from claims on the natural world (e.g. Boyle, 2000).

[7] Descartes (1996 [1644], Part 2, §§16, 37). Descartes took himself to have established substantive truths on the physical world a priori: see his (1996a [1637], pp. 63-64, trans. pp. 143–144). He did not include empirical confirmation or verifiability among the 'conditions' that philosophical principles must meet (1996a [1637], p. 9, trans. p. 183).

[8] Boyle (2001, vol. 3, p. 171); see Sprat (1667, pp. 108-109, 257); Hooke (1726, p. 26). For examples of Boyle's theory-testing experiments, see Cecon (2015, pp. 83-85).

[9] A case in point is Locke's commitment to corpuscularism. Given his pessimism on the possibility to discover the sub-microscopic constitution of material bodies (Anstey, 2011, pp. 31-45), this commitment is best regarded as weak or tentative.

[10] For instance, on the arts as a subject of natural histories, see Boyle (2008 [1666], p. 3); Hooke (1705a, p. 18).

[11] See, e.g., Henry Oldenburg's introduction to Rooke (1665, p. 140).

[E5] Natural philosophical theories should be derived from experimental natural histories through a process of induction (Glanvill, 1668, p. 87; Hooke, 1705b, p. 331). Yet, experimental philosophers did not take up Bacon's elaborate theory of induction, nor did they develop detailed accounts of how theories can be derived from empirical evidence.

Some of these claims were not unique to experimental philosophers. For instance, the emphasis on first-person experiences can be found in works by Aristotelian anatomists (Wear, 1983, pp. 227-230), Galileo, and his disciples that predate the emergence of experimental philosophy.[12] However, neither the Aristotelians, nor Galileo held that natural philosophers should follow a two-stage method ([E2]) or compile experimental natural histories ([E4]). The endorsement of all five claims is distinctive of experimental philosophers.

2. Experimental philosophy, anglocentrism, and Montanari's method

Experimental philosophy, as characterized above, was not an intrinsically British phenomenon. Any authors who endorsed and followed its method could qualify as experimental philosophers, regardless of their geographical location. However, most of the studies on early modern experimental philosophy which have been published so far note its presence in England (Anstey, 2004, 2005, 2009; Chalmers, 2012; Dear, 1990; Gaukroger, 2006, pp. 352-399), Ireland (Hemmens, 2015), and Scotland (Gomez, 2012; Malet, 2013; Poovey, 1998). Based on these studies, one might think that experimental natural philosophy was largely a British phenomenon. This is often suggested in the literature. For instance, Peter Dear and John Henry hold that '[t]he term "experimental philosophy" is associated with a characteristically English approach to the study of nature' (Dear, 1990, p. 663; see Henry, 2008, p. 55). And Steven Shapin (1996, p. 85) states that the two-stage method of experimental philosophers was developed by many 'practitioners, especially in England'.

In response, it would be easy to provide a battery of quotes that provide *prima facie* evidence for the uptake of experimental philosophy in late seventeenth-century Italy or eighteenth-century France and Spain. As regards Italy, for instance, one can find endorsements of the method of experimental philosophy by authors based in Bologna (Montanari, 1667, pp. 5-7), Florence,[13] and Messina (Scilla, 1996 [1670]), in addition to authors who worked throughout the Peninsula (Malpighi, 1980 [1698]), and even Jesuits teaching in Brescia (Lana Terzi, 1977 [1670]) and Rome (Bartoli, 1980 [1677]).

Such a broad survey, however, is unlikely to convince the sceptics. They may reply that these authors' endorsement of experimental philosophy was a merely strategic move that concealed their real aims. For instance, according to Luciano Boschiero (2007), Lorenzo Magalotti portrayed the Accademia del Cimento as a strictly experimentalist organization to conceal the deep natural philosophical divergences between its corpuscularist and Aristotelian members. If this is the case, then none of the members of the Cimento might have been strongly committed to experimental philosophy. As for Jesuits like Bartoli and Lana Terzi, while they were enthusiastic in their praise of experimentalism, they were also keen to show its compatibility with Scholastic natural philosophy. These concurrent commitments gave rise to hybrid natural philosophies that went well beyond the epistemological and methodological strictures of experimental philosophy. Broad surveys are not effective tools to conclusively establish to what extent experimental philosophy was influential on the Continent. They are too superficial to distinguish substantive commitments from merely rhetorical, half-hearted, or inconsistent commitments.

A more fruitful approach is analyzing the natural philosophical practice, commitments, and pronouncements of specific authors in some detail. Montanari is an ideal subject for such an analysis for two reasons. First, he wrote extensively on a broad range of topics. Between 1667 and his death in 1687, he published works on acoustics (Montanari, 1715 [1678]), astronomy,[14] ballistics (1690), fluid mechanics (1667), and the quenching of glass.[15] He also wrote on hydraulics (e.g. 1715 [1684]), the physics of typhoons (1694), and the Torricellian vacuum.[16] Second, Montanari's published works and the extant manuscript material[17] show that he had explicit, self-conscious views on how we should proceed in natural philosophy, views to which I now turn.

Montanari criticizes earlier authors, especially the Scholastics, for adopting what experimental philosophers regarded as the typical way of proceeding of their speculative opponents. Their 'most evident error' was starting by 'establishing the first principles of natural things, which are the last and most remote of all the cognitions that we can attain by philosophizing' (Montanari, 1980, p. 542). For instance, Aristotle attempted to explain motion by formulating its 'essential definition', 'which he very obscurely established to be *actus entis in potentia prout in potentia*, and by stating how many kinds of motion there are'.[18] '[N]early all great minds' followed Aristotle in philosophizing from first principles because, 'being too self-confident, they did not carefully ponder the capacities of the human mind, which is not only finite and limited, but also confined within very narrow boundaries' (1980, pp. 539-540). Having developed contrasting theories on such flimsy foundations, philosophers started quarrelling with each other, rather than studying the natural world. Following Bacon, Montanari states that they got embroiled in verbal disputes and became more

[12] e.g. Ciampoli (1665, pp. 16-17). This book was composed before 1644.

[13] Magalotti (1667, Proemio a lettori, sig. +2 4, trans. p. 92).

[14] e.g. Montanari (1671a), which proves the existence of variable stars, and Montanari (1676). Newton (1999 [1726], pp. 913-915, 927) relies on Montanari's observations of the Great Comet of 1680, as Rotta (1971, pp. 78-79, 88-89, 150n72) noted.

[15] Montanari (1671b). The Royal Society decided to translate this work into English and publish it, but this project was never completed. See Cavazza (1990, pp. 135-137).

[16] Montanari (1694 [1675]). As far as we know, he did not make experiments with Boylean vacuum using air-pumps. On the introduction of air-pumps in Italian academies, see Pighetti (1988, pp. 34, 139-147). Montanari was born in Modena in 1633. He started engaging in natural-philosophical research in earnest in 1657–1658, during a stay in Vienna. There, he collaborated with Paolo del Buono, one of the last pupils of Galileo. After a stint in Florence, where he established ties with members of the Cimento, he took up a position as astronomer at the Modena court. He then moved to Bologna, where he became university professor of mathematics in 1664 and he founded the Accademia della Traccia in 1665. During these years, Montanari strengthened his reputation as an astronomer. Among other things, he was the first to record the periodic fluctuations in the brightness of a star (Algol). Together with his wife Elisabetta, he ground lenses and built telescopes and microscopes. In 1678 he moved to the University of Padua, where a well-paid professorship in astronomy and meteorology was created for him. He refused to include astrology in his astronomy classes, instead intensifying his campaign against astrological beliefs. As part of his duties, he often collaborated with the Venetian government as a consultant on water engineering and economics, in line with his belief in the practical usefulness of the new science. He died in Padua in 1687.

[17] See especially Montanari (1971, 1980) which, in all likelihood, are faithful transcriptions of Montanari's manuscripts by his pupil, Francesco Bianchini.

[18] Montanari (1980, p. 549); see (1971, p. 197). The quote from Aristotle is from *Phys*. III 202 a 7–8. Barnes (1984, vol. 1, p. 37) translates it as 'the fulfilment of the movable as movable'.

concerned to obtain dialectical victories over their opponents than to find the truth.[19]

Instead, philosophers should 'start' from 'particular things, examining the whole of nature piece by piece and amassing a rich capital of experiences, so as to prepare the [natural] historical material on whose basis one will later have to speculate concerning reasons' (Montanari, 1980, pp. 539-540). In other words, one must start by adopting the way of proceeding recommended by Boyle—'that great anatomist of nature' (Montanari, 1694 [1675], p. 301; see 1676, p. 49; 1980, p. 544). As Montanari writes, echoing the motto of the Royal Society, one must doubt 'all philosophical assertions, which are sanctioned as true solely for the authority of the Schools', and derive philosophical 'maxims from experience, which alone has the privilege of being a credible teacher' (Montanari, 1667, pp. 5-6).

By itself, the claim that cognition starts from experience is not particularly innovative. Every Aristotelian would have endorsed it. However, unlike the Aristotelians, Montanari mentions *experiences* [*esperienze*, *experimenta*], in the plural, much more often than *experience*. In his view, we should not start from the *experientia longa* of the Aristotelians, which arises gradually in the course of time from many sensed events that left a trace in memory (Baroncini, 1992, p. 164). Montanari's *esperienze* are distinct events which, ideally, have been (*a*) *personally observed*, (*b*) *replicated* experimentally, and (*c*) made the object of extended *experimental series*. Let us pause briefly on each of these points.

Montanari's emphasis on the first-person character of experiences emerges from his polemical tirade against Heron of Alexandria:

> I reasoned that I can certainly learn little from him, who imagined experiences or accepted other people's experiences without examining them by himself. Sadly, this is a deplorable practice not only of many ancients, including even Aristotle, who included many false experiences in his works, but also of many moderns. Once they are pleased by some philosophical thought of theirs, they do not have any qualms to confirm it with experiences that they did not see and that, in practice, turn out in the opposite way than what they say. By doing this, they contaminate the credibility of philosophy and they make it impossible to philosophize on the works of nature on the basis of solid foundations.[20]

Montanari's emphasis on first-person experiences is not merely rhetorical. A significant portion of the activity of the Accademia della Traccia, that he led, was devoted to replicating the experiments of the Cimento and others. One can note the results of this activity in Montanari's published works. For instance, in his treatise on capillary action (1667, pp. 17-18, trans. p. 102), he points out that an experiment proposed by the Jesuit Honoré Fabri yields a result which is different from what he claimed and inconsistent with his theory.

Unlike some of his contemporaries, Montanari does not rely on the gentlemanly status of those who participated in the experiments[21] or on princely supervision[22] to warrant the reliability of experimental reports. He does not place any emphasis on the roles or identities of specific members of his academy, including himself, even though he was its leader and its most knowledgeable member. Nor does he strictly adhere to the first-person narrative style privileged by Francesco Redi (1996 [1668]) and some of his disciples (e.g. Zambeccari, 1980 [1680]). He sometimes uses an impersonal form corresponding to the English passive voice ('was taken', 'was repeated', etc.)[23] In his view, what warrants the accuracy of an experimental report is the replicability of the experiment, as part of a 'collaborative, public, and accessible' process of inquiry (Bennett, 2003, p. 82).

Whenever we are to rely on an *esperienza*, we should seek to repeat it multiple times, as Montanari often notes that he did (e.g. Montanari, 1715 [1678], p. 23). However, if we are searching for causes, the multiple repetition of one single experience is of limited help. We should develop an *experimental series* which, for Montanari as for Bacon, Boyle, or Redi,[24] starts with an experiment and then varies the experimental parameters one by one. We should keep 'changing circumstances' until we find 'the one which, when changed, determines a change in the effect' (1676, p. 62). Montanari carefully explains how he employed this process in specific inquiries, like the study of the quenching of glass (1971, pp. 200-201).

Montanari was aware that this method is not applicable across the board. Certain astronomical and meteorological phenomena, like sightings of comets, are rare, cannot be replicated experimentally, and must be studied on the basis of the reports of others' observations. Montanari's treatise *On the Flying Flame*, on the comet of 1676, shows that he approaches his correspondents' reports in a critical way. On occasion, he asks them to repeat their observations or he inquires into the accuracy of the latitude and longitude data on which they rely.[25] However, he is ready to admit that the uniqueness or rarity of some experiences sets a limit to our understanding:

> I confess that I cannot understand [what certain lights that had been seen in the sky are]. This may be for the weakness of my understanding or, perhaps, because I am used to philosophizing with experiences under my eyes, examining them, repeating them as much as I please, modifying the circumstances until I find the one which, once it is changed, changes the effect, and then I start my reasoning from it (Montanari, 1676, p. 62).

Although experiments have the advantage of reproducibility over observations, Montanari does not emphasize the difference between experiments and observations. His *esperienze* encompass experiments and observations alike.[26] It may be tempting to impute this to Montanari's lack of conceptual subtlety. However, he had a good reason for including experiments and observations within a single category. The reason is that, as is the case for Bacon, Boyle, and Hooke,[27] experiments and observations have the same

[19] Montanari (1667, pp. 3-5). He refers to Bacon in his (1971, p. 197). Montanari's comments bring to mind Hooke's contrast between 'the *real*, the *mechanical*, the *experimental* Philosophy' and the 'Philosophy of *discourse* and *disputation*' (Hooke, 1665, Preface, sig. *a* 3). However, it is unclear whether Montanari read Hooke's *Micrographia* (Rotta, 1971, p. 90; Gómez López, 1997, pp. 34n, 105n85).

[20] Montanari (1694 [1675], pp. 290-291; see 1694, p. 22; 1980, p. 542). As was mentioned, not only experimental philosophers, but also anatomists emphasized the importance of first-person experience. However, anatomy was not one of Montanari's main interests (Rotta, 1971, pp. 113-115).

[21] See Shapin (1994) on the Royal Society.

[22] See Findlen (1993, p. 53) on Francesco Redi.

[23] e.g. Montanari (1667, p. 9; 1671b, p. 16; 1780, p. 722).

[24] For examples of Bacon's, Boyle's, and Redi's experimental series, see respectively Jalobeanu (2016); Cecon (2015, p. 86); Bernardi (1996, pp. 15-16).

[25] Montanari (1676, pp. 21-23). The combination of first-person experiences with experiences reported by others (not natural philosophers, but *prattici*) is also apparent in Montanari's works on hydraulics (e.g. his 1715 [1684], pp. 46-47, 49, 51, 56-57).

[26] Montanari's Italian contemporaries used the term "esperienza" in the same broad way. For instance, Redi's *Esperienze* (1996 [1668]) includes experiments as well as observations.

[27] See Anstey (2014b).

primary function in Montanari's natural philosophy: providing 'historical material'[28] which is the basis for explanations.

Unlike the works of other *novatores* like Redi, Montanari's experimental works typically contain two key sections: a natural-historical section and an explanatory section.[29] Reports of experiments and observations form the natural-historical section. They provide 'historical material' because they are little natural histories of the phenomena that each work aims to explain. They share the three features of experimental natural histories mentioned in Section 1. Montanari's miniature natural histories (1) are not mostly on biological kinds, but on inanimate objects like comets, natural processes like capillary action, and artificial processes like the quenching of glass. These processes (2) are often brought about by experiments and (3) they are the basis for natural philosophical explanations. Montanari (1980, p. 540) acknowledges that his models for the compilation of natural histories are the 'most learned Bacon of Verulam' and 'the Royal Academicians of London'.

In line with the two-stage method of his philosophical models,[30] Montanari complements the natural-historical section of his works with a section identifying 'reasons' [*cagioni*], that is, theories and explanations of the phenomena described in the first section.[31] Like Boyle and Hooke, Montanari does not provide any detailed, elaborate account of how *cagioni* are to be derived from *esperienze*. He only states that what is needed is an induction,[32] but he does not explain how it unfolds. He sometimes mentions *deduction* where one would expect to find mentions of induction,[33] leaving his readers as puzzled as Newton's (1999 [1726], p. 943) readers as to how, exactly, a 'deduction from the phenomena' is supposed to work.

Montanari holds that, once we have gathered enough experiences, we can use them to choose among competing theories because experiences are more trustworthy than theories. In his view, properly performed experiments yield 'matters of fact that, unlike theories, are not subjected to dispute'.[34] This is why he employs experiments to prove or refute theories, like Fabri's theory of capillary action (1667, pp. 17-18, trans. p. 102). Montanari's lectures are explicit in asserting the primacy of experiments and observations over both theories and any kind of non-sensory cognition.[35] He states that we cannot firmly establish anything on issues like the nature of the infinite or the relation between body and soul (1971, p. 199), because they fall beyond the bounds of sense. He carefully refrains from taking a stance on such issues.

The foregoing survey of Montanari's natural philosophical method shows that the endorses the distinctive claims of seventeenth-century experimental philosophers ([E1] to [E5]). He holds that empirical information should be collected by means of first-person experiences ([E3]), that fact gathering should precede theory building ([E2]), and that we should only commit ourselves to those substantive claims and theories on the natural world that are warranted by extensive experiments and observations ([E1]). He develops experimental natural histories ([E4]). He speaks of induction or deduction from the phenomena, but he does not provide a detailed account of this process ([E5]). He singles out the same friends and foes of experimental philosophers: he criticizes Aristotle and the Scholastics for following a wrong method, while praising Bacon and Boyle.[36] We can then state that experimental philosophy was not a merely British phenomenon because at least one prominent Italian natural philosopher, namely Montanari, was thoroughly committed to it.

While this survey shows that experimental philosophy was not *exclusively* a British phenomenon, it is insufficient to establish whether it was *largely* a British phenomenon. In order to assess this claim, it is necessary to analyze the natural philosophical views of numerous authors working in Italy, France, Germany, the Netherlands, and Spain. This article is part of a series of studies that are devoted to that task and that, collectively, chart the chronological and geographical spread of early modern experimental philosophy.[37] On its own, this reconstruction of Montanari's views shows that at least one Italian author was thoroughly committed to experimental philosophy as early as in the 1660s.

3. Experiments, theories, and explanations

According to Luciano Boschiero, Montanari's commitment to experimental philosophy—like a similar commitment of the Cimento academicians—was not substantive. It was a merely rhetorical posture which played only a 'persuasive and authoritative role'.[38] In this section, I discuss an argument that can be used to support that claim. I call it the argument from inconsistency. The argument concludes that Montanari's adherence to experimental philosophy was a merely rhetorical posture because it was inconsistent with central features of his natural philosophy. One can identify three putative inconsistencies:

1. *Pace* Gómez López (1997, p. 15n), Montanari is not 'convinced that the sole task of a scientist is observing nature and performing experiments'. He holds that we should 'deduce' explanations from experiments and observations (Montanari, 1676, p. 17). He provides explanations of capillary action, the quenching of glass, the origin of typhoons, and so on. By providing explanations, besides reports of experiments and observations, Montanari trespasses the boundaries of experimental philosophy, which was a 'purely descriptive' form of research.[39] In the

[28] Montanari (1980, p. 539), quoted above.

[29] These may be combined with other sections, like a literature review (1667, pp. 14-26) or the testing of the theory's predictions (1715 [1684], pp. 84-89). I disagree with Boschiero's (2009, p. 205) suggestion that 'Alcune Esperienze' (1780) departs from the two-part structure. This text does not start with a discussion of the corpuscular structure of liquids, but with the exposition of a series of experiments (pp. 721-723). Redi's works typically have a traditional three-part structure (*status quaestionis*; literature review; experimental reports: see Bernardi, 1996, p. 13n14) and they lack an explanatory section.

[30] See Section 1, point [E2].

[31] Montanari (1980, p. 539). Occasionally, theories appear in the natural-historical section as hypotheses to be tested or as heuristic tools to devise further experiments.

[32] Montanari (1971, p. 197; 1980, p. 540).

[33] e.g. Montanari (1667, p. 45; 1980, p. 549).

[34] Clericuzio (2005, p. 220) with reference to Boyle; see Wood (1980, p. 12) with reference to Sprat; Gómez López (1997, p. 231) with reference to Montanari.

[35] Besides sensory cognition, there is only one other kind of 'exact cognition': our innate, God-endowed knowledge of basic mathematical truths. However, we can use it only by relying on sense experience. See Montanari (1971, p. 199; 1980, pp. 542, 543).

[36] On occasion, he also criticizes Descartes (Montanari, 1694, p. 112), whose works he read in 1657–1658 (Rotta, 1971, p. 153n97). Given the cultural context of seventeenth-century Italy (Maffioli, 1994, pp. 30-31), it is far from surprising that Montanari criticizes the Scholastics more frequently than Descartes.

[37] On Italy, see also Vanzo (unpubl.). On France, see Anstey (2014a, in press). On Germany, see Vanzo (2015). On the Netherlands, see the unpublished papers presented at the workshop 'Early eighteenth-century experimental philosophy in the Dutch Republic' (Brussels, 7 July 2014, <http://www.vub.ac.be/FILO/?p=677>, archived at <http://www.webcitation.org/6cLdxCIAC>, accessed 20 October 2015). On Spain, see Gomez (in press).

[38] Boschiero (2007, p. 9) on the Cimento; see Boschiero (2009) on Montanari.

[39] Cavazza (1998). Shapin and Schaffer (1985) endorse roughly the same view. They claim that Boyle 'banned' (p. 203) or 'tactically segregated' the search for causes 'from the main tasks of the natural philosopher' (p. 147, see p. 205).

words of the Cimento's secretary, the sole aim of experimental philosophy was '*experimenting* and *narrating*'.[40]

2. Even granting that experimental philosophers can consistently put forward explanations, they should build them on an adequate empirical basis. Seventeenth-century experimental philosophers identified this basis with a universal natural history. They held that one should raise 'new Axiomes or Theories' only after such a history is completed (Hooke, 1705a, p. 18). Montanari appears to endorse this view. He states that,

> in order to find what the true, first, and most universal principles of all things might be, it is not sufficient to make an induction from few terms. It is necessary to first cognize all natural effects, so that one can later find a common reason that accounts for all experiences. But who can already boast to possess such universal information? (Montanari, 1980, p. 540)

The answer, of course, is: nobody. And so, if Montanari had been coherent with his own methodological prescriptions, he should have refrained from putting forward explanations of capillary action, the quenching of glass, or typhoons until a universal natural history was completed. Montanari's explanations are inconsistent with the method of experimental philosophy because he provides them too early.

3. Montanari's explanations go well beyond the limits of what he could experience. They postulate the existence of unobserved, theoretical entities such as corpuscles. Montanari goes as far as to ascribe specific properties to different kinds of corpuscles. For instance, he claims that the corpuscles of liquids must be in constant movement (Montanari, 1980, p. 549) and that they must be convex, like little spheres or like Descartes' spindle-shaped particles (1780, pp. 724-725; see Descartes, 1996b [1637], p. 233, trans. p. 264). Montanari's claims on theoretical entities such as corpuscles are inconsistent with the method of experimental philosophy. This is supposed to be 'detached from theoretical convictions or presuppositions' (Boschiero, 2007, p. 9) or, at least, to replace 'micro-corpuscularian explanations' with phenomenal, 'non-reductive explanations' that avoid any commitment to unobserved entities (Gaukroger, 2006, p. 254).

The argument from inconsistency fails because Montanari's views are consistent with the tenets of experimental philosophy on all three counts. Of the three charges, the first is the easiest to rebut. It relies on a flawed understanding of experimental philosophy. If the account provided in Section 1 is correct, experimental philosophy as such is not a purely descriptive enterprise. Only its first stage is descriptive, because it aims to assemble observations and experiments and to organize them into natural histories. However, natural histories are intended to provide the basis for explanations. That these have full citizenship within experimental philosophy can be seen from the fact that the second stage of inquiry is entirely devoted to providing explanations.

This brings us to the second charge. It is true that Montanari provides explanations before the completion of a universal natural history. However, this is in contrast neither with experimental philosophy as such, nor with Montanari's specific views on how we should practise it. As we saw in Section 1, the ban of experimental philosophers on 'new Axiomes or Theories' is best understood as the view that we should not *firmly* or *strongly* commit ourselves to theories or explanations before extensive empirical investigations have been carried out. Before then, we can still make a weak commitment to theories.

Montanari's natural philosophical activity is in line with this stance. He does not pretend that he carried out experiments and observations in a theoretical void. For instance, when he was instructing his correspondents on what information they should gather about the newly appeared comet of 1676, he was clearly being guided by astronomical theories. Montanari does not conceal this.[41] He never claims that we should refrain from entertaining or *provisionally* endorsing theories and explanations while we are engaged in experiments and observations. His method only requires that we do not attempt to *conclusively* establish which natural philosophical views are correct before we have gathered enough experiences.

How many experiences are enough? This depends on which phenomena we seek to explain. Montanari holds that his experiences are insufficient to provide a comprehensive, basic, detailed theory of the natural world. However, they are sufficient to explain specific phenomena, like capillary action and the quenching of glass. The passage quoted in support of the second charge is in line with this view. It states that we will establish the 'true, first and most universal principles *of all things*' only once we have completed a universal natural history (Montanari, 1980, p. 540, italics added). It does not require us to complete a universal natural history before establishing the principles *of specific phenomena* as well. On the contrary, Montanari holds that we can explain more specific phenomena before turning to more general or more basic phenomena (1980, pp. 541-542). For instance, we can explain capillary action with the hypothesis of the viscosity of liquids, even though we have not carried out the 'great number of experiments and speculations' that 'would be required' to 'understand entirely the origin' of viscosity.[42] Instead of grounding all explanations on first principles, as the Aristotelians sought to do, we should advance gradually toward the first principles by seeking the causes of specific phenomena and then progress toward higher levels of generality. This is because

> it is certainly easier to find a universal conclusion for those who have learnt many particular conclusions on the same subject than for those who are entirely ignorant of its specific features.[43]

Montanari's explanations put this strategy into practice. They are cautious intermediate steps in the ascent along the ladder of causes (Bacon, 2000 [1605], II, §7).

The third charge concerns the fact that Montanari's explanations ascribe existence and specific features to unobserved, theoretical entities such as corpuscles. However, the method of experimental philosophy does not prohibit one to make claims on unobserved, sub-microscopic entities. It only requires one to justify any such claims with arguments based on experience,[44] as opposed to a priori arguments like those with which Descartes (1996 [1644], Part II, §20) established that all corpuscles are divisible.

[40] Magalotti (1667, Proemio a lettori, sig. +2 4, trans. p. 92). To be sure, this passage states that it was the sole aim of the Cimento, not of experimental philosophy as such.

[41] Mordechai Feingold makes the same remark with regard to the Cimento academicians (Beretta, Feingold, Findlen, & Boschiero, 2010, p. 197).

[42] Montanari (1667, p. 30, trans. p. 108). Similarly, Bianchini (1785 [*ca.*1687], pp. 21-23) claims that we should accept the explanation of muscle contraction in terms of fermentation, even though we lack an explanation of fermentation in corpuscular terms.

[43] Montanari (1980, p. 550). Boyle too (1999 [1661], pp. 21, 23) endorses this procedure.

[44] Montanari (1980, p. 549) acknowledges this with regard to the ascription of specific properties to corpuscles. Sargent (1989, pp. 35, 36) notes that for Boyle too the corpuscular hypothesis must be proven a posteriori.

Although Montanari's arguments for the *existence* of corpuscles are not as detailed as we would like them to be,[45] they are clearly empirical arguments. For instance, the argument of 'Alcune Esperienze' concludes that liquids are made up of corpuscles because certain observed facts are consistent with their existence and inconsistent with their non-existence (Montanari, 1780, p. 724). They include the facts that liquids can be split into tiny parts; that when a liquid touches a surface, its parts can easily detach and stick to it; and that liquids can fill containers of any shape. Regardless of whether this argument is convincing, the facts on which it is based are empirical facts. The same holds for the argument of the *Physico-Mathematical Thoughts* on the corpuscular nature of air, which is based on 'experiences' of rarefaction and condensation.[46]

Montanari's arguments for ascribing specific *properties* to corpuscles are empirical arguments too. For instance, he notes that,

> although water appears to be still, it dissolves salt or other soluble bodies that were placed on the bottom of [a recipient full of] water and that did not seem to move. Having seen this, I deduce that the parts of water are in constant motion. Otherwise, they could not spread the particles of that salt everywhere and all parts of the liquid would not become equally salty. The deduction is so manifest that, although it makes a supposition about invisible things, it is established with necessity, so that I can subsequently deduce other consequences about nature from it.[47]

Montanari stresses that, when he and other *novatores* ascribe 'invisible' motions to 'invisible particles', they do so on the basis of experience. They 'deduce' the motion and properties of corpuscles from the 'effects of natural things' (1980, p. 546), 'from sensory experiences, or at least from that great argument from probability, namely that, given those suppositions, one can easily solve many, many physical problems' which are raised by puzzling observations.[48]

In this regard, it is interesting to note that Montanari confines his theoretical commitments to what he deems necessary to explain the phenomena at hand. He could easily use certain topics as a springboard to tackle hotly debated questions. Yet, he often refrains from entering in the fray. For instance, the discussion of the quenching of glass (1671b) gave Montanari the opportunity to comment on the corpuscular structure of bodies, the existence of the vacuum, and the nature of heat. Yet, he steers clear of those topics.[49] In some cases, having made a claim on unobserved entities, Montanari adds that it is unnecessary to settle certain contended issues regarding them. For instance, after claiming that the particles of liquids are convex, he states that there is no need to determine their specific shape or to agree with Descartes that they are spindle-shaped. The mathematical principle at the basis of his explanations holds regardless of which specific shape the particles have (1780, pp. 724, 731-732). Nor is it necessary to grant that the interstices between particles are empty, 'because' his arguments 'equally satisfy those philosophers who sustain the vacuum and those who deny it' (1667, p. 29, trans. p. 108). These statements by Montanari are more cautious than those of most Italian *novatores* who discuss similar issues in works published between 1660 and 1690, including Giovanni Alfonso Borelli, Tommaso Cornelio, Urbano Davisi, Giuseppe Del Papa, Leonardo Di Capua, Lucantonio Porzio, and Donato Rossetti.[50]

Montanari also displays a 'strong dose of modesty' (Heilbron, 2010, p. 45) in his theoretical writings, which are a dialogue on the vacuum and lecture notes on corpuscles. He denies that we know whether all corpuscles are divisible[51] (and praises Boyle for his neutrality on this issue[52]); what shape the corpuscles of air may have; whether *minima*, assuming they exist, are uncreated or incorruptible; and whether the *minima* of a given substance retain its macroscopic properties (Montanari, 1980, pp. 547-548). What we lack to settle these issues is sufficient empirical evidence. Whereas sensory experience gives us 'light', speculating on what we have not experienced is like walking in the dark (1694 [1675], pp. 274, 277). Our views on such matters are 'fantasies' that can be 'narrated', not demonstrated (p. 293). They may legitimately 'incline' us toward certain views, but they cannot 'determine' us to firmly endorse them (p. 292).

To summarize, the argument from inconsistency fails to prove that Montanari's endorsement of experimental philosophy is merely rhetorical, rather than substantive. Montanari provides explanations of several phenomena. He does so before the completion of a universal natural history. He makes claims on unobserved entities. However, he does not violate the methodological strictures of experimental philosophy. This is because neither experimental philosophy, nor Montanari's methodological views ban explanations. They allow one to make a weak, tentative, or provisional commitment to explanations and theories; to accept explanations of specific phenomena before the completion of a universal natural history; and to progress gradually to explanations of more general or more basic phenomena. They also allow for the ascription of existence and properties to theoretical entities, as long as it is based on empirical arguments. Montanari's explanations satisfy these constraints.

4. Experimental philosophy and mechanical philosophy

Since Montanari's adherence to experimental philosophy was not merely rhetorical, but substantive, we can use it as a test case to assess some recent claims on the relation between experimental philosophy and mechanical philosophy. According to Alan Chalmers (2012) and Stephen Gaukroger (2006, pp. 254, 397; 2014, p. 28), the relation between experimental philosophy and mechanical philosophy as such is 'in many respects antagonistic' (Gaukroger, 2006, p. 254). In this context, "mechanical philosophy" is to be understood in broad sense, as combining commitments to corpuscles (corpuscularism) and to explaining physical phenomena according to the laws of mechanics (mechanism). It is the view that physical phenomena should be explained in terms of the shape, size, and spatial arrangement of the corpuscles that make up

[45] In this respect, too, Montanari resembles Boyle. See Meinel (1988, p. 70).

[46] Montanari (1667, p. 27, trans. p. 107). A further argument for the existence of corpuscles is in Montanari (1980, pp. 544-545).

[47] Montanari (1980, p. 549). Similarly, observed facts concerning liquids require their corpuscles to be convex (1780, pp. 724-725).

[48] Montanari (1980, p. 549). I have found no evidence for Gómez López's (1997, p. 17) claim that Montanari is disinterested in whether such suppositions are true or false.

[49] Montanari is equally cautious in his discussions of the origin of sunspots and other astronomical issues. See Rotta (1971, pp. 85-88).

[50] Borelli (1686 [1670–1672], prop. 123-125) ascribes, albeit cautiously, specific figures to the *minima* of air and liquids; Cornelio (1688, p. 387) to water corpuscles; Davisi (1667, p. 11) to the *minima* of vapour; Del Papa (1674, pp. 65-71) to calorific corpuscles; Di Capua (1683, pp. 70-71, 121, 142, 154) to calorific corpuscles and to those of air and alkali. Porzio (1736 [1667]) indulges in hypotheses on the shape of the corpuscles of liquids, despite his professed agnosticism on the matter. Rossetti (1667) ascribes, among other things, three basic instincts or tendencies and various energy levels to the *minima*.

[51] Montanari (1980, p. 545).

[52] Montanari (1980, p. 544) with reference to Boyle (1999 [1666–1667]) or to Boyle (1999 [1661]). The latter work was widely read in Italy.

bodies, along with the motion of those corpuscles according to the laws of mechanics.[53] According to Chalmers (2012, p. 551), mechanical philosophy aimed to identify 'the rock-bottom or ultimate causes of material phenomena'. Instead, experimental philosophy 'was concerned with the identification of specific, experimentally-accessible, non-ultimate, causes such as pressure, weight and chemical affinity'. Along similar lines, Gaukroger (2006, p. 254) claims that experimental philosophers offered

> non-reductive explanations, which made no reference to micro-structure, but which its adherents treated as complete, by contrast with the mechanist commitment to micro-corpuscularian explanations as the ultimate form of explanation. The experimental apparatus on which experimental philosophers relied 'produces a certain range of phenomena which defy explanation in fundamental terms' (Gaukroger, 2006, p. 397). '[W]hat is happening here can fruitfully be described in terms of the experiment or instruments bringing a domain of investigation into focus, *replacing* the underlying structure that would traditionally have occupied this role'.[54]

Montanari's works on fluid mechanics, hydraulics, and the quenching of glass provide counterexamples to this characterization of the relation between experimental and mechanical philosophy. Many of the examples and references of the previous sections are drawn from those works. This is because they are entirely in line with the dictates of experimental philosophy. Yet, they are far from exemplifying the alleged antagonism between experimental and mechanical philosophy. In those works, Montanari does not rely on experiments or instruments to replace inquiries into the underlying corpuscular structure of phenomena with inquiries into 'phenomena which defy explanation in fundamental terms' (Gaukroger, 2006, p. 397), nor does he stop at intermediate, non-ultimate causes, as opposed to 'the rock-bottom or ultimate causes of material phenomena' (Chalmers, 2012, p. 551). He relies on observations, experiments, and instruments to establish a set of facts, as one would expect from an experimental philosopher. He then explains those facts in terms of the properties of 'rock-bottom or ultimate' material causes—corpuscles—and their behaviour according to the laws of mechanics. For instance, having identified certain observable properties of liquids, Montanari argues that they require their constituent corpuscles to be convex. He then explains the observed properties of liquids in terms of the shape and behaviour of their corpuscles.

Montanari does not isolate these corpuscular-mechanical explanations from the experimental sections of his works. On the contrary, he embeds corpuscular-mechanical explanations within the method of experimental philosophy in three ways. To begin with, he develops them during the second, explanatory stage of that method. Moreover, he develops them on the basis of information gathered in the first, natural-historical stage. Finally, he sometimes formulates predictions on the basis of those explanations and he goes on to test them experimentally. For instance, having provided a corpuscular-mechanical account of capillary action, he argues that, if the account is correct, 'liquids rise in the little straws in inverse proportion to their diameters' (Montanari, 1667, p. 40, trans. p. 113) and he provides experimental evidence for that claim. He does not present this evidence simply as an illustration, but as an '*argument* of the truth' of his corpuscular-mechanical 'suppositions' (p. 42, trans. p. 113). Rather than as an alternative to corpuscular-mechanical explanations, Montanari uses experiments and observations as a tool to establish them. This shows that, *pace* Chalmers and Gaukroger, experimental philosophy as such was not 'antagonistic' to mechanical philosophy.[55]

In conclusion, the reconstruction of Montanari's natural philosophical method supports three claims. First, experimental philosophy was not an exclusively British phenomenon. At least one prominent Italian author adhered to the dictates of experimental philosophy explicitly, thoroughly, and consistently as early as in the 1660s. Second, in order to be a consistent experimental philosopher, it was not necessary to reject any theories, suspend any theoretical commitments, and be engaged in a purely descriptive, fact-gathering enterprise. Montanari provides an example of how natural philosophers could endorse explanations of physical phenomena and make claims on unobserved, theoretical entities in a way that is consistent with the dictates of experimental philosophy. Third, Montanari's case shows that experimental philosophy and mechanical philosophy were not, as such, opposed to one another. Early modern authors could combine their commitments to experimental and mechanical philosophy within a single natural philosophical project.

The question remains of the extent to which Montanari's views were representative of broader trends. As was mentioned in Section 2, several other natural philosophers in seventeenth-century Italy endorsed the method of experimental philosophy. However, some of those endorsements may be merely rhetorical or half-hearted. It is easy to find authors who, like Montanari, adhered to experimental philosophy as well as mechanical philosophy, not only in Italy but also in Britain. Two prominent examples are Robert Boyle and Robert Hooke, who have been even said to use 'experimental philosophy' and 'mechanical philosophy' as synonymous (Webster, 1967, p. 165n66). Yet, John Keill (1702, pp. 3-4, trans. 2-3) and others portrayed experimental and mechanical philosophy as two distinct movements. More research is needed to establish which authors, especially on the Continent, endorsed the method of experimental philosophy thoroughly rather than superficially, and who among them embraced mechanical philosophy in a way that was consistent with their experimentalism. This paper has contributed to the ongoing project of charting the spread of experimental philosophy and its relations with corpuscularism and mechanism.

Acknowledgements

I would like to thank Tom Sorell and the participants in the 4th Bucharest Colloquium in Early Modern Science for valuable comments on earlier versions of this article. This work was supported by a Marie Curie International Incoming Fellowship within the 7th European Community Framework Programme and by the Arts and Humanities Research Council [grant number AH/L014998/1].

References

Anstey, P. Bacon, experimental philosophy and French Enlightenment natural history. In R. Garrod, K. Murphy, P. J. Smith (Eds.), *Natural history in early modern France*: *The poetics of an epistemic genre* Leiden: Brill [in press].

[53] In this paper, I am not concerned with mechanical philosophy understood as the view that physical phenomena should be explained by analogy with the functioning of machines.

[54] Gaukroger (2006, p. 397), italics added.

[55] Another Italian author who combined experimental philosophy and mechanical philosophy in a similar way to Montanari was Domenico Guglielmini: see Vanzo (unpubl.) Antonio Felice Marsili (1671, pp. 306-307), who like Guglielmini was a pupil of Montanari, portrays Democritus as an exemplar experimental *and* mechanical philosopher. He praises Democritus both for performing extensive experiments and for explaining natural phenomena in terms of the figures and motion of atoms.

Anstey, P. R. (2004). The methodological origins of Newton's queries. *Studies in History and Philosophy of Science, 35*, 247-269 (Available at http://dx.doi.org/10.1016/j.shpsa.2003.11.001)

Anstey, P. R. (2005). Experimental versus speculative natural philosophy. In P. R. Anstey, & J. A. Schuster (Eds.), *The science of nature in the seventeenth century: Patterns of change in early modern natural philosophy* (pp. 215-242). Dordrecht: Springer (Available at http://dx.doi.org/10.1007/1-4020-3703-1_9)

Anstey, P. R. (2009). The experimental history of the understanding from Locke to Sterne. *Eighteenth-Century Thought, 4*, 143-169.

Anstey, P. R. (2011). *John Locke and natural philosophy*. Oxford: Oxford University Press.

Anstey, P. R. (2014a). D'Alembert, the 'Preliminary Discourse' and experimental philosophy. *Intellectual History Review, 24*, 495-516 (Available at http://dx.doi.org/10.1080/17496977.2014.970370)

Anstey, P. R. (2014b). Philosophy of experiment in early modern England: The case of Bacon, Boyle and Hooke. *Early Science and Medicine, 19*, 103-132 (Available at http://dx.doi.org/10.1163/15733823-00192p01)

Bacon F. (2000 [1605]). *The advancement of learning*. M. Kiernan (Ed.). Oxford: Oxford University Press.

Barnes, J. (Ed.). (1984). *The complete works of Aristotle*. Princeton: Princeton University Press.

Baroncini, G. (1992). *Forme di esperienza e rivoluzione scientifica*. Florence: Olschki.

Bartoli, D. (1980 [1677]). Da 'La tensione e la pressione disputanti qual di loro sostenga l'argento vivo ne' cannelli dopo fattone il vuoto'. In M. L. Altieri Biagi, & B. Basile (Eds.), *Scienziati del Seicento* (pp. 1191-1201). Milan: Ricciardi.

Bennett, J. (2003). Hooke's instruments. In J. Bennett, M. Cooper, M. Hunter, & L. Jardine (Eds.), *London's Leonardo: The life and work of Robert Hooke* (pp. 63-104). New York: Oxford University Press.

Beretta, M., Feingold, M., Findlen, P., & Boschiero, L. (2010). Regress and rhetoric at the Tuscan court. *Metascience, 19*, 187-210 (Available at http://dx.doi.org/10.1007/s11016-010-9320-8)

Bernardi, W. (1996). Introduzione. In W. Bernardi (Ed.), *F. Redi, Esperienze intorno alla generazione degl'insetti*. Florence: Giunti.

Bianchini, F. (1785 [*ca.*1687]). Dissertazione di Monsignor Francesco Bianchini. In *Nuova raccolta d'opuscoli scientifici, e filologici* (Vol. 41) Venice: Occhi.

Borelli, G. A. (1686 [1670–1672]). *De motionibus naturalibus, a gravitate pendentibus*. Leiden: Vander; trans. *Borelli's On the movement of animals – On the natural motions resulting from gravity*. P. Maquet (Ed.) Springer: Dordrecht, 2015.

Boschiero, L. (2007). *Experiment and natural philosophy in seventeenth-century Tuscany: The history of the Accademia del Cimento*. Dordrecht: Springer (Available at http://dx.doi.org/10.1007/978-1-4020-6246-9)

Boschiero, L. (2009). Networking and experimental rhetoric in Florence, Bologna and London during the 1660s. In M. Beretta, A. Clericuzio, & L. M. Principe (Eds.), *The Accademia del Cimento and its European context* (pp. 195-210). Sagamore Beach, Mass.: Science History Publications.

Boyle, R. (1999 [1661]). Certain physiological essays. In M. Hunter, & E. B. Davis (Eds.), *The works of Robert Boyle* (Vol. 2, pp. 3-203). London: Pickering and Chatto.

Boyle, R. (1999 [1662]). Defence against Linus. In M. Hunter, & E. B. Davis (Eds.), *The works of Robert Boyle* (Vol. 3, pp. 3-107). London: Pickering and Chatto.

Boyle, R. (1999 [1666–1667]). The origin of forms and qualities according to the corpuscular philosophy. In M. Hunter, & E. B. Davis, *The works of Robert Boyle* (Vol. 5, pp. 281-491). London: Pickering and Chatto.

Boyle, R. (2000). The requisites of a good hypothesis. In M. Hunter, & E. B. Davis (Eds.), *The works of Robert Boyle* (Vol. 13, pp. 270-272). London: Pickering and Chatto.

Boyle, R. (2001). *Correspondence of Robert Boyle*. London: Pickering and Chatto.

Boyle R. (2008 [1666]). *The text of Robert Boyle's 'Designe about natural history'*. M. Hunter and P. R. Anstey (Eds.) http://www.bbk.ac.uk/boyle/researchers/works/Occasional_Papers/occasional_paper_3.pdf, archived at http://www.webcitation.org/6cKFdOKNL, accessed 20.10.15.

Cavazza, M. (1990). *Settecento inquieto: Alle origini dell'Istituto delle Scienze di Bologna*. Bologna: Il Mulino.

Cavazza, M. (1998). Review of S. Gómez López, *Le passioni degli atomi*, *Universitas*, *11* (May 1998). http://www.cis.unibo.it/NewsLetter/111998Nw/cavazza.htm, archived at http://www.webcitation.org/6VNibjk7x, accessed 20.10.15.

Cecon, K. (2015). Robert Boyle's experimental programme: Some interesting examples of the use of subordinate causes in chymistry and pneumatics. *Intellectual History Review, 25*, 81-96 (Available at http://dx.doi.org/10.1080/17496977.2014.891185)

Chalmers, A. (2012). Intermediate causes and explanations: The key to understanding the Scientific Revolution. *Studies in History and Philosophy of Science, 43*, 551-562 (Available at http://dx.doi.org/10.1016/j.shpsa.2012.06.005)

Ciampoli, G. (1665). Della filosofia naturale […] fragmento primo. In *Dei fragmenti dell'opere postume […] saggio primo* (pp. 1-81). Venice: Giunti.

Clericuzio, A. (2005). *La macchina del mondo: Teorie e pratiche scientifiche dal Rinascimento a Newton*. Rome: Carocci.

Cornelio, T. (1688). *Progymnasmata physica* (2nd ed.). Naples: Raillard.

Davisi, U. (1667). *Due lettere: In una delle quali da sensate sperienze si deducono alcuni effetti meteorologici, e nell'altra si dimostra la vera origine de' fonti, e de' fiumi*. Bologna: Ferroni.

Dear, P. (1990). Miracles, experiments, and the ordinary course of nature. *Isis, 81*, 663-683 (Available at http://dx.doi.org/10.1086/355544)

Del Papa, G. (1674). *Lettera intorno alla natura del caldo e del freddo*. Florence: Livi.

Descartes, R. (1996a [1637]). *Discours de la méthode*. In *Œuvres*. C. Adam & P. Tannery (Eds.), J. Beaude & P. Costabel (Rev.). Paris: Vrin; trans. in J. Cottingham, R. Stoothoff, D. Murdoch, & A. Kenny (Eds.), *The philosophical writings of Descartes* (Vol. 1, pp. 111-151). Cambridge: Cambridge University Press, 1984.

Descartes, R. (1996b [1637]). *Les météores*. In *Œuvres*. C. Adam & P. Tannery (Eds.), J. Beaude & P. Costabel (Rev.). Paris: Vrin; trans. in P. J. Olscamp (Ed.), *Discourse on method, Optics, Geometry, and Meteorology* (pp. 263-361). Indianapolis: Bobbs-Merrill, 1965.

Descartes, R. (1996 [1644]). *Principes de la philosophie*. In *Œuvres*. C. Adam & P. Tannery (Eds.), J. Beaude & P. Costabel (Rev.). Paris: Vrin; partial trans. in J. Cottingham, R. Stoothoff, D. Murdoch & A. Kenny (Eds.), *The philosophical writings of Descartes* (Vol. 1, pp. 177-291). Cambridge: Cambridge University Press, 1984.

Di Capua, L. (1683). *Lezioni intorno alla natura delle mofete*. Naples: Castaldo.

Dunton, J. (1692). *The Young-Students-Library*. London.

Findlen, P. (1993). Controlling the experiment: Rhetoric, court patronage and the experimental method of Francesco Redi. *History of Science, 31*, 35-64 (Available at http://dx.doi.org/10.1177/007327539303100102)

Gaukroger, S. (2006). *The emergence of a scientific culture: Science and the shaping of modernity, 1210–1685*. Oxford: Oxford University Press.

Gaukroger, S. (2014). Empiricism as a development of experimental natural philosophy. In Z. Biener, & E. Schliesser (Eds.), *Newton and empiricism* (pp. 15-38). New York: Oxford University Press (Available at http://dx.doi.org/10.1093/acprof:oso/9780199337095.003.0002)

Glanvill, J. (1668). *Plus ultra*. London.

Gomez, J. (2012). The progress of Scotland and the experimental method. In J. Maclaurin (Ed.), *Rationis Defensor: Essays in honour of Colin Cheyne* (pp. 111-124). Dordrecht: Springer (Available at http://dx.doi.org/10.1007/978-94-007-3983-3_9)

Gomez, J. Scholastics and novatores: The scientific debate. In H. Braun, & E. DeBom. *A companion to the Spanish Scholastics*. Leiden: Brill [in press].

Gómez López, S. (1997). *Le passioni degli atomi: Montanari e Rossetti*. Florence: Olschki.

Heilbron, J. L. (2010). Francesco Bianchini and natural philosophy. In L. Ciancio, & G. P. Romagnani (Eds.), *Unità del sapere molteplicità dei saperi: Francesco Bianchini (1662–1729) tra natura, storia e religione* (pp. 33-73). Verona: QuiEdit.

Hemmens, S. (2015). Crow's nest and beyond: Chymistry in the Dublin Philosophical Society, 1683–1709. *Intellectual History Review, 25*, 59-80 (Available at http://dx.doi.org/10.1080/17496977.2014.891187)

Henry, J. (2008). *The Scientific Revolution and the origins of modern science* (3rd ed.). Basingstoke: Palgrave.

Hooke, R. (1665). *Micrographia*. London.

Hooke, R. (1705a). A general scheme, or idea of the present state of natural philosophy. In R. Waller (Ed.), *The posthumous works of Robert Hooke* (pp. 1-70). London.

Hooke, R. (1705b). Lectures and discourses of earthquakes and subterraneous eruptions. In R. Waller (Ed.), *The posthumous works of Robert Hooke* (pp. 279-450). London.

Hooke, R. (1726). Dr. Hook's method of making experiments. In W. Derham (Ed.), *Philosophical experiments and observations of the late eminent Dr. Robert Hooke* (pp. 26-27). London: Innys.

Hooke, R. (1726 [1692]). Dr. Hook's discourse concerning *telescopes and microscopes*. In W. Derham (Ed.), *Philosophical experiments and observations of the late eminent Dr. Robert Hooke* (pp. 257-268). London: Innys.

Hunter, M. (1995). *Science and the shape of orthodoxy: Intellectual change in late seventeenth-century Britain*. Woodbridge: Boydell Press.

Jalobeanu, D. (2016). Disciplining experience: Francis Bacon's experimental series and the art of experimenting. *Perspectives on Science, 24*, 324-342 (Available at http://dx.doi.org/10.1162/POSC_a_00209)

Keill, J. (1702). *Introductio ad vera physicam: Seu lectiones physicae*. London: Bennet; trans. *Introduction to Natural Philosophy: Or, Philosophical Lectures*. London: Innys, 1726.

Lana Terzi, F. (1977 [1670]). *Prodromo all'Are Maestra*. A. Battistini (Ed.) Milan: Longanesi.

Locke, J. (1975 [1690]). *An essay concerning human understanding*. P. Nidditch (Ed.) Oxford: Clarendon.

Maffioli, C. S. (1994). *Out of Galileo: The science of waters, 1628–1718*. Amsterdam: Erasmus Publishing.

Magalotti, L. (1667). *Saggi di naturali esperienze fatte nell'Accademia del Cimento*. Florence; trans. in W. E. K. Middleton, *The Experimenters: A study of the Accademia del Cimento* (pp. 83-254). Baltimore: Johns Hopkins Press, 1971.

Malet, A. (2013). Between mathematics and experimental philosophy: Hydrostatics in Scotland about 1700. In D. Garber, & S. Roux (Eds.), *The mechanization of natural philosophy* (pp. 159-187). Dordrecht: Springer (Available at http://dx.doi.org/10.1007/978-94-007-4345-8_7)

Malpighi, M. (1980 [1698]). Risposta […] alla lettera intitolata: 'De recentiorum medicorum studio dissertatio epistolaris ad amicum'. In M. L. Altieri Biagi, & B. Basile (Eds.), *Scienziati del Seicento* (pp. 1065-1184). Milan: Ricciardi.

Marsili, A. F. (1671). Delle sette de' filosofi, e del genio di filosofare. In *Prose de' signori accademici Gelati di Bologna* (pp. 299-318). Bologna: Manolessi.

Meinel, C. (1988). Early seventeenth-century atomism: Theory, epistemology, and the insufficiency of experiment. *Isis, 79*, 68-103 (Available at http://dx.doi.org/10.1086/354634)

Montanari, G. (1667). *Pensieri fisico-matematici sopra alcune esperienze […] intorno diversi effetti de' liquidi in cannuccie di vetro, & altri vasi*. Bologna: Manolessi; partial trans. in B. Dooley (Ed.), *Italy in the Baroque: Selected readings* (pp. 100-115). New York: Garland, 1995.

Montanari, G. (1671a). *Sopra la sparizione d'alcune stelle et altre nouità celesti*. Undated work, probably published in Bologna in 1671.
Montanari, G. (1671b). *Speculazioni fisiche […] sopra gli effetti di que' vetri temprati, che rotti in una parte si risolvuono tutti in polvere*. Bologna: Manolessi.
Montanari, G. (1676). *La fiamma volante*. Bologna: Manolessi.
Montanari, G. (1690). *Manualetto de bombisti* (3rd ed., enlarged). Venice: Poletti.
Montanari, G. (1694). *Le forze d'Eolo*. Parma: Poletti.
Montanari, G. (1694 [1675]). Discorso del vacuo. In G. Montanari, *Le forze d'Eolo* (pp. 271-312). Parma: Poletti.
Montanari, G. (1715 [1678]). *Discorso sopra la tromba parlante*. Venice: Albrizzi.
Montanari, G. (1715 [1684]). Il mare Adriatico e la sua corrente esaminata, & la naturalezza de fiumi scoperta, e con nuove forme di ripari corretta. In G. Montanari, *Discorso sopra la tromba parlante* (pp. 41-130). Venice: Albrizzi.
Montanari, G. (1780). Alcune esperienze […] sopra l'equilibrio di diversi liquidi in alcuni vasi […]. In G. Targioni Tozzetti (Ed.), *Notizie degli aggrandamenti delle scienze fisiche accaduti in Toscana nel corso di anni LX del secolo XVII* (Vol. 2, pp. 721-734). Florence.
Montanari, G. (1971). Dalla 'Compendiosa introductio at physicam experimentalem'. In *Miscellanea Seicento* (Vol. 2, pp. 197-201) Florence: Le Monnier.
Montanari, G. (1980). Della natura et uso degli atomi o sia corpuscoli appresso i moderni. In M. L. Altieri Biagi, & B. Basile (Eds.), *Scienziati del Seicento* (pp. 537-552). Milan: Ricciardi.
Newton, I. (1999 [1726]). *The Principia: Mathematical principles of natural philosophy*. I. B. Cohen and A. Whitman (Eds.) Berkeley: University of California Press.
Oldroyd, D. R. (1987). Some writings of Robert Hooke on procedures for the prosecution of scientific inquiry, including his 'Lectures of things requisite to a natural history'. *Notes and Records of the Royal Society, 41*, 145-167 (Available at http://dx.doi.org/10.1098/rsnr.1987.0002)
Pighetti, C. (1988). *L'influsso scientifico di Robert Boyle nel tardo '600 italiano*. Milan: Franco Angeli.
Poovey, M. (1998). *A history of the modern fact: Problems of knowledge in the sciences of wealth and society*. Chicago: University of Chicago Press.
Porzio, L. (1736 [1667]). Del sorgimento de' licori nelle fistole aperte d'ambedue gli estremi. In F. Porzio (Ed.), *Opera omnia, medica, philosophica, et mathematica* (Vol. 2, pp. 323-371). Naples: Cajetani.
Power, H. (1664). *Experimental philosophy*. London.
Redi, F. (1996 [1668]). *Esperienze intorno alla generazione degl'insetti*. W. Bernardi (Ed.) Florence: Giunti.
Rooke, L. (1665). Directions for sea-men, bound for far voyages. *Philosophical Transactions, 1*, 140-143 (Available at http://dx.doi.org/10.1098/rstl.1665.0069)
Rossetti, D. (1667). *Antignome fisico-matematiche*. Livorno: Bonfigli.
Rotta, S. (1971). Scienza e 'pubblica felicità' in G. Montanari. In *Miscellanea Seicento* (Vol. 2, pp. 65-208). Florence: Le Monnier.
Sargent, R.-M. (1989). Scientific experiment and legal expertise: The way of experience in seventeenth-century England. *Studies in History and Philosophy of Science, 20*, 19-45 (Available at http://dx.doi.org/10.1016/0039-3681(89)90032-0)
Scilla, A. (1996 [1670]). *La vana speculazione disingannata dal senso*. M. Segala (Ed.) Florence: Giunti.
Shapin, S. (1994). *A social history of truth: Civility and science in seventeenth-century England*. Chicago: University of Chicago Press.
Shapin, S. (1996). *The Scientific Revolution*. Chicago: University of Chicago Press.
Shapin, S., & Schaffer, S. (1985). *Leviathan and the air-pump: Hobbes, Boyle, and the experimental life*. Princeton: Princeton University Press.
Sprat, T. (1667). *The history of the Royal Society of London for the improving of natural knowledge*. London.
Vanzo, A. (2015). Christian Wolff and experimental philosophy. *Oxford Studies in Early Modern Philosophy, 7*, 225-255.
Vanzo, A. (unpubl.) Corpuscularism and experimental philosophy in Domenico Guglielmini's *Reflections* on Salts. Unpublished manuscript.
Wear, A. (1983). William Harvey and the 'way of the anatomists'. *History of Science, 21*, 223-249 (Available at http://dx.doi.org/10.1177/007327538302100301)
Webster, C. (1967). Henry Power's experimental philosophy. *Ambix, 14*, 150-178 (Available at http://dx.doi.org/10.1179/amb.1967.14.3.150)
Wood, P. (1980). Methodology and apologetics: Thomas Sprat's History of the Royal Society. *British Journal for the History of Science, 13*, 1-26 (Available at http://dx.doi.org/10.1017/S0007087400017453)
Zambeccari, G. (1980 [1680]). Dalle 'Esperienze intorno a diverse viscere tagliate a diversi animali viventi'. In M. L. Altieri Biagi, & B. Basile (Eds.), *Scienziati del Seicento* (pp. 853-870). Milan: Ricciardi.