Scientific method in John Buridan

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There is little point to enumerate all the diverse opinions that still mark the study of medieval natural philosophy, and especially its methodology. It is enough to point out that while some authors reproach medieval science for its over-rationality,[1] others argue that modern science emerged precisely because of the refutation of over-empiricism that had characterized its medieval antecedent.[2] The present paper picks out only one specific aspect of this cluster of problems, together with one specific author, that is, the meaning and role of 'experiment' in the treatise on vacuum in the *Physics* commentary of John Buridan. While the experimental method is often regarded as a main characteristic of modern science distinguishing it from its predecessors, John Buridan (ca. 1300—1358) was undoubtedly the most influential natural philosopher in fourteenth-century Paris.[3] Thus, examining this crucial concept in the natural philosophy of Buridan might help to situate it in the more general medieval framework; beside this, this examination will also have some consequences regarding the much-debated issue of the relationship between Buridan's methodological practice and theory. In the first section I present an overview and a possible categorization of Buridan's experiments, which shows that these experiments were in certain respects remarkably different from those that are regarded as experiments today. In the second section I examine how these experiments relate to Buridan's theory of science, and argue that his methodological practice is strongly dependent on his methodological theory.

I. Experiments and Imaginations: A Possible Taxonomy

Throughout his commentary on Aristotle's *Physics*, and especially in the questions on the vacuum,[4] Buridan uses several kinds of arguments, from purely logical reasoning to experimental examples. His "experiments" include simple everyday observations, some more designed experiments, as well as experiments that probably were never performed but were believed on authority, together with some even more abstract demonstrations *secundum imaginationem*.

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1 E.g., Richard Hooykaas, *Religion and the Rise of Modern Science* (Grand Rapids, MI: William B. Eerdmans Publishing Company, 1972), 87.

2 Peter Dear, *Discipline and Experience: The Mathematical Way in the Scientific Revolution* (Chicago: The University of Chicago Press, 1995), 4, 29-30.

3 Buridan has been receiving increasing attention in the last few decades. For a philosophical introduction to his logic, semantics, and metaphysics, see Gyula Klima, *John Buridan* (Oxford: Oxford University Press, 2009). For a more historical study of his life, see Jack Zupko, *John Buridan: Portrait of a Fourteenth-Century Arts Master* (Notre Dame: University of Notre Dame Press, 2003).

4 That is, book IV, questions 7-11 in the same work.

A. *Secundum Experientiam:* Experience and Observation

The first group of examples Buridan uses to support or demonstrate his theses are the performed, or at least *in theory* performable experiments. One might further divide this category to that of simple everyday observations, more specific experiences, and in-theory-performable, but in fact not performed experiments. (These are, of course, not categories with sharp-cut borders, and one might draw the division differently.)

(1) Simple Observations

There are certain experiments that are rather just a direct kind of awareness of everyday phenomena. Thus, before presenting the main argument against the possibility of vacuum, Buridan raises some objections which would point to an opposite conclusion.[5]

One of them derives from local movement. If straight local movement exists, void also has to exist because a body, moving along a straight line, obviously moves to *some* place. Now if in that place there is nothing, then some void exists; if there is a body, then – since two bodies cannot be at the same place at the same time – this body also has to move. However, in this latter case, repeating the question for this second body and so on, the absurd consequence would follow that whenever something moves rectilinearly, the whole of the heavens would have to move with it. As can be observed, a premise of the argument – which argument, to be sure, can already be found in almost exactly the same form in Aristotle, as well as in Grosseteste's and John of Jandun's commentary[6] – is grounded in experience, namely that there *is* something that moves rectilinearly.

The other three objections found in the same *questio* are similar; they argue from rarefaction, condensation, and augmentation. The argument is, again, rather simple. If rarefaction, condensation, or augmentation exists, then void also has to exist; but one can observe the former, therefore the conclusion (i.e., there is void) follows. Condensation or rarefaction is usually imagined as a kind of local movement where the particles comprising the matter either come closer to or further away from each other, respectively. That, however, is not possible either without the void receiving the particles (as in the argument taken from local movement), or without vacuum being produced between them.[7]

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[5] All of them may be found in the *Questiones super octo libros Physicorum libros Aristotelis* (Paris: 1509, Reprint: Frankfurt, a. M.: Minerva, 1964) (hereafter 'QP'), IV, q. 7.

[6] Robertus Grosseteste, *Commentarius in VIII Libros Physicorum Aristotelis,* ed. R. Dales (Boulder: University of Colorado Press, 1963) (hereafter 'GQP'), 85; also *Ioannis de Ianduno philosophi acutissimi super octo libros Aristotelis de Physico auditu subtilissimae quaestiones* (Paris: 1551, Reprint: Frankfurt a. M.: Minerva, 1969) (hereafter 'JQP'), fol. 59 rb B.

[7] QP fols. 72 vb–73 ra; it is also found in Grosseteste, GQP 85, and in John of Jandun, JQP fol. 59 rb B.

These examples, therefore, are not so much experiences of a concrete instance than that of a general principle or characteristics of nature. Buridan does not direct the reader to specific examples of rectilinear motion; he only refers to the general phenomenon. While replying to these objections, he does not consider the above experiences as experiences, but only their - previously incorrect - explanation. The key to his reply lies in the concept of condensation and rarefaction, which, according to Buridan, are not describable by local movement, but are quantitative changes, enabling in turn straight local movement and augmentation as well.[8]

(2) Specific Experiences

In the same part of the same question, however, Buridan also uses some more specific experiments which require a more attentive design, or a more creative interpretation. Showing that condensation and rarefaction must indeed exist, he refers to the experience of fermenting wine. As he describes it, wine fermenting in a well-made jar can increase in volume so much that it can break the jar; or, air could be rarefied in such a way that if a jar is only half-filled with wine this wine can come out through a hole in the bottom, although nothing enters the jar to refill it. Condensation can also be observed if a bottle is heated above a fire and its orifice put into water afterwards; in this case, when the air in the bottle cools down, it condenses, so that the water ascends in the bottle. Moreover, if a slat is bent intensely, as in the case of a bow, its concave surface will be much shorter than the convex one, which can only come about by the violent condensation of the interior, and the rarefaction of the exterior parts.[9]

A similarly common, concrete example was meant to support Buridan's thesis that nature abhors a vacuum. The experiment was made with a hollow reed with one end placed in wine; if someone, having the other end of the straw in his mouth, draws up the air that was in the reed, the wine follows the air upwards although it is heavy. That shows that nature prevents the formation of a vacuum so strongly that it forces the wine to follow the air immediately whenever the air is drawn out.[10] Similarly to the previous examples, this experience must have been rather common, and indeed, many similar descriptions can be found from antiquity.[11]

In another place, Buridan makes use of the example of the pendulum. Having argued that the medium through which a body descends is not the only resisting force that can cause finite

8 QP IV, q. 11.

9 QP fol. 77 vb.

10 QP fol. 73 va.

11 For its history, see Edward Grant, *Much Ado about Nothing: Theories of Space and Vacuum from the Middle Ages to the Scientific Revolution* (Cambridge: Cambridge University Press), 80-81; it is also apparent in Roger Bacon *Questiones Supra Libros Octo Physicorum Aristotelis,* ed. F. M. Delorme (Oxford: Clarendon Press, 1935), 230, and in JQP fol. 60 vb E.

speed in the motion of a falling heavy body, he refers to the lead in the pendulum, which, while moving, is not only resisted by the air, but even more by the cord tied to it.[12]

As these examples already suggest, there are some remarkable characteristics in the medieval concept of *experimentum* which seem not to be found in the modern one. First, as with the pendulum or the fermenting wine in a jar, the experiments do not necessarily require more than observations from everyday life. And this is their advantage: they would have hardly been questioned by anyone, and were, indeed, widely used in natural philosophical reasoning. In the thirteenth century, for instance, Arnald of Villanova explicitly argues in favor of everyday experiences:

> For since the properties of things cannot be discovered by reason but only by experiment or revelation, and experience and revelation are common to the ordinary man and to the scholar, it is possible that knowledge of properties may be attained by the common people sooner than by others.[13]

Therefore, if one were to acquire knowledge of the properties of things, one should not despise the experiences of everyday people but rather use them. Buridan does so not only in these *questiones,* but throughout his commentary; he uses experience in arguments even in the famous passage of the impetus-theory, where he refers to such instances as the smith's mill, or a loaded ship pulled on a river.[14]

Secondly, the medieval concept was broader than the modern one in even yet another sense. As Roger Bacon notes,

> All doubted [things] become known by certitude, and all errors are dissolved by the solid truth. But in mathematics we can come to the entirety of truth without error, and to all certitude without doubt: because in mathematics we come to truth by demonstration through the proper and necessary cause [*demonstrationem per causam propriam et necessariam*]. And the demonstration makes us to know the truth. And similarly, it also contains *the sensible example of everything, and the sense experience of drawing and counting, so that everything is manifest to the senses*: because of this, we cannot have doubt in mathematics.[15]

According to Bacon, mathematics is the most certain of the sciences precisely because it is *experiential*: all of its theses and demonstrations rely on experience. Experience is, therefore,

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12 QP fol. 75 ra.

13 *Repetitio super vita brevis;* quoted and transl. by Lynn Thorndike, "Roger Bacon and Experimental Method in the Middle Ages," *The Philosophical Review* 23 (1914): 289: *Nam cum notitiam proprietatum non possit haberi per rationem sed tum experimento vel revelatione, et experientia et revelationes sunt communes vulgo et sapientibus, possibile est ut proprietatum notitiae prius habeantur a vulgaribus quam ab aliis.*

14 Cf. QP VIII, q. 12.

15 *The 'Opus Majus' of Roger Bacon,* ed. John H. Bridges (Oxford: Clarendon Press, 1897), I, 105—106. (Unless otherwise indicated, translations are mine; also my emphasis here): *Omne dubium fit notum per certum et omnis error evacuatur per solidam veritatem. Sed in mathematica possumus devenire ad plenam veritatem sine errore, et ad omnium certitudinem sine dubitatione: quoniam in ea convenit haberi demonstrationem per causam propriam et necessariam. Et demonstratio facit nos cognosci veritatem. Et similiter in ea contingit haberi ad omnia exemplum sensibile, et experientiam sensibilem figurando et numerando ut omnia ad sensum manifestentur: propter quod non potest esse dubitatio in ea.*

anything that can be observed, be it a sensory experience of external objects, an observed figure in geometry, or even our own act of counting.

What clearly distinguishes this concept of *experience* - together with the first two kinds of Buridan's *experientia* - from modern *experiments* (the medieval authors usually used the two terms interchangeably) is the concept of experiment as intervention, which can be clearly seen in a passage by Francis Bacon stating what is explicitly denied by Aristotle. According to Bacon, "the secrets of nature reveal themselves more readily under the vexations of art than when they go their own way."[16] On the contrary, in the *Physics*, Aristotle clearly distinguished between things by nature and things created by art; the *differentia specifica* of the former is precisely that they contain their principles of motion in themselves.[17] Thus, nature is nature *just insofar as* it goes its own way; it can only be observed as long as it remains undisturbed. The Baconian concept of nature, which today is rather obvious for scientists, would have been extremely problematic for an ancient as well as for a medieval thinker: the principles of nature cannot be studied unless allowed to act spontaneously.[18]

(3) Not Performed Experiments

Buridan's third kind of experiment are those that were described but presumably not performed by Buridan or his readers; their outcome was accepted either because an authority or a supposedly expert person affirmed it, or because it easily followed from already accepted principles.

One of the most interesting examples of this category is the following *experimentum,* presented again as a *sed contra* argument in favor of the existence of vacuum. If there is a pot filled with ashes, one can pour just as much water in it as if it were empty. The advocate of the possibility of vacuum interprets the experiment by saying that this is only possible if a void exists between the specks of the ashes.[19] (The other variant, the existence of two bodies in the same place, is dismissed as evidently self-contradictory.)

This experiment already appears in Aristotle, who, in turn, traces it back to earlier authors not mentioned by name.[20] Averroes's treatment of it is worth quoting in its entirety, for his treatment is the one Buridan refers to in his solution.

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[16] Francis Bacon, *The New Organon and Related Writings*, ed. Fulton H. Anderson (New York: The Liberal Arts Press, 1960), 95. (*Novum Organum* I, 98)

[17] Cf. *Physics* 192 b8-35.

[18] Bacon's concept of nature was not without antecedents. The vexation of art is most apparent in medieval magic, which, in this respect, is truly a forerunner of modern science. See Frances Amelia Yates, *Giordano Bruno and the Hermetic Tradition* (Chicago: University of Chicago Press, 1964).

[19] QP fol. 73 va.

[20] *Physics*, 213 b20.

> And there is another argument, which is brought up as a proof by those who say that vacuum exists. Namely, they say that the same jar receives just as much water when it is full of ashes as when it is empty. And this I have not experienced, but if it is indeed so as they say, it has no other reason than the water being destroyed by the ashes, either entirely, if we assumed that between the parts of ashes there is no air distributed in such a way that no parts of it remain in it (except some quality); or it is destroyed partly, and parts of the air, which is mixed with the ashes, emerge, while some parts of the ashes are dissolved. And this latter is more probable. And its sign is that when the ashes are squeezed, some parts of the water come out of them, but not all, and when the ashes dry out, [their quantity] becomes less than it was before.[21]

The passage, in itself, is quite obscure. Buridan summarizes its content saying that if the ashes are hot and dry, then they cause a great part of the water evaporate, while the remainder can enter into the fine parts of the ashes which were previously occupied by the air.[22] What is, however, more important from a methodological point of view is that Averroes, as he rightly admits, never performed the experiment – this might at least partly explain its obscurity – but concerning its outcome, he believes those who have allegedly carried it out. (Interestingly, Autrecourt, when describing the experiment with reference to Averroes, accuses him of "neglecting such an easy experiment."[23] Whether he himself made it, of course, cannot be determined, but it is at least questionable.)

Buridan probably never performed it either. However, this "neglect" of Averroes, as well as of Buridan, whose solution was the same, is partly explainable by the fact that their main point did not concern the experiment *as* an experiment (Averroes could have, for example, objected to the circumstances or means of its performance or could have questioned its outcome, which neither he nor his medieval followers did), but was rather about its theoretical interpretation. Averroes gave another explanation for the same observable phenomenon, showing therefore that this observation alone does not necessarily involve the existence of a vacuum. Accordingly, Buridan also does not discuss the experiment itself, and he even omits the closing words of Averroes's passage, where the Commentator at least gives a reason for choosing one interpretation over the other.

There is another experiment with a rather long history that is meant to prove that nature abhors vacuum, that is, that "we cannot separate one body from another, unless some other body

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21 Averroes, *Aristotelis De Physico Auditu Libri Octo, Cum Averrois Cordubensis Variis in Eosdem Commentariis* (Venetiis apud iunctas, 1562, Reprint: Frankfurt a. M.: Minerva, 1962), fol. 149M-150A: *Et hec est alia ratio particularis: et induxit ipsam pro testimonio dicentium vacuum esse. Dicunt nam quod idem vas tantum capit de aqua quando est plenum cinere, quantum capit de aqua quando est vacuum. Et ex hoc non sum expertus, et si est, sicut dicunt, non habet aliam causam nisi quia aqua corrumpitur a cinere, aut secundum totum, si dixerimus quod inter partes cineris non est aer divisus ita quod ex eo non remaneat in eo nisi qualitas tantum, aut corrumpantur ex ea partes aliquae, et aeri, qui est mixtus cum cinere, succedunt ex eo partes aliques, et dissolvuntur a cinere aliae partes, et hoc est verius. Et signum eius est quoniam quando cinis exprimitur exit quedam pars aque ab eo et non tota, et quando cinis desiccatur, revertitur minor quam erat.*

22 QP fol. 73 vb.

23 *The Universal Treatise of Nicholas of Autrecourt,* transl. R. Arnold et al. (Milwaukee: Marquette University Press, 1971), 94.

intervenes."[24] By expelling the air from a bellows, which results in its sides collapsing and coming into contact, and by completely closing all its openings so that no air could enter, Buridan argues that one could never separate their surfaces. "Not even twenty horses could do it if ten were to pull on one side and ten on the other,"[25] he claims, so greatly does nature resist the possibility of producing a vacuum.

This bellows experiment, which for Buridan was an experiment against the possibility of nature producing a void, later had quite a bright career.[26] In this form, it cannot be found either in Grosseteste or in Roger Bacon (the latter, though, uses far more *experimenta* than Buridan does), but in a much less elaborated form it is apparent in the *Physics* commentary of John of Jandun,[27] who describes it briefly as if it would have been familiar and evident to any of his readers.

Later, it was used by the Jesuits in the *Physics* commentary written at the University of Coimbra, and in the *Physics* commentary of Franciscus Toletus.[28] When, however, it encountered the anti-Aristotelian supporters of the vacuum in the sixteenth century, the experiment took a new turn. Bernardino Telesio, for example, transforms the whole experiment by stating that the sides of the bellows could be easily separated if the force applied was large enough and the bellows strongly built. He insists that the scholastics failed precisely because they did not pay much attention to the appropriate means and circumstances of the experiment. He uses, therefore, basically the same experiment as Buridan (but with a different outcome) to show exactly the opposite thesis; as he explains, when the sides of the bellows are separated, void is produced between them.[29]

Then, the history moves on to Otto von Guericke, the inventor of the air pump in the second half of the 1650s, who was perhaps the first person to actually perform the experiment. He joined two copper hemispheres (the so-called "Magdeburg hemispheres"), and pumped the air out of the sphere; then, tying eight horses to each hemisphere, he showed that they could not separate them. As can be seen, the outcome of the experiment – although the means are slightly different from Buridan's – is the same; Guericke, however, like Bernardino Telesio, draws the opposite conclusion and interprets his experiment as disproving the hypothesis of *horror vacui.*[30]

In Buridan's case, however, this *experimentum*, is rather a thought-experiment; whether it was not performed because of technical difficulties (it would not have been easy to pump the air

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24 QP IV, q. 7, fol. 73 va: *Nos experimur quod non possumus unam corpus ab alio separare quin interveniat aliud corpus.*

25 Ibid: *Immo nec viginti equi hoc posset si decem traherent ad unam partem et decem ad aliam.*

26 For sixteenth-century developments, see Charles B. Schmitt, "Experimental Evidence for and against a Void: The Sixteenth-Century Arguments," *Isis* 58 (1967): 352—66.

27 JQP IV, q. 11, fol. 60 vb

28 For quotation and full references, see Charles B. Scmitt, "Experimental Evidence for and against a Void…", 355.

29 Bernardino Telesio, *De Rerum Natura*, ed. Vincenzo Spampanato, 3 vols. (Modena: Formiggini, 1910-1923), vol. I, 88.

30 His description of the experiment is found in Otto von Guericke, *Experimenta Nova (Ut Vocatur) Magdeburgica De Vacuo Spatio* (Amsterdam: Apud Joannem Janssonium a Waesberge, 1672).

completely out of a bellows, seal it hermetically, and really attach it to twenty horses, especially because the air-pump had not yet been invented), or simply because it was thought to be unnecessary, probably can never be clearly determined. The context and the mode of expression, however, at least indicates that for Buridan it was not a kind of *experimentum crucis* (a concept, to be sure, which did not even exist in his time), but only an illustration or example. While he has no doubt about the outcome of the experiment, he does not bother at all about its possible – either technical, or theoretical – difficulties, nor with the question of why would one need twenty horses exactly to demonstrate nature's resistance to a vacuum.

All in all, these experiments (even despite their occasional actual falsity, as with the pot with the ashes) were mostly accepted by everyone because other authors confirmed them.[31] This either implicit or explicit reliance on authority was, indeed, a common feature of medieval natural philosophical reasoning.[32] As even Roger Bacon argued for it,

> First one should be credulous until experience follows second and reason comes third. … At first one should believe those who have made experiments or who have faithful testimony from others who have done so, nor should one reject the truth because he is ignorant of it and because he has no argument for it.[33]

Accordingly, the experiment (supposedly) performed by another respected author had the same force in the argumentation as the one performed by the author itself. Ancient books are often referred to as *experientiae,* as for instance the *Geometry* of Plinius and Marcianus in Grosseteste.

B. *Secundum Imaginationem*

The last remark leads to the second main group in Buridan's arguments – the even theoretically unrealizable *secundum imaginationem* demonstrations. Depending on the subject these thought experiments often occupy the majority of Buridan's argumentation. They are not simple imaginings in the sense that anything could be imagined, but resting on some elementary principles, they

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31 Although not in the commentary of Buridan, there is another famous, often-used, but never performed simple false example, which perhaps first appeared in Johannes Canonicus, but was still used in the fifteenth century. Arguing for the possible existence of void, a well-seled jar full of water is said to have been put outside in winter; when the water freezes, it is said to condense, therefore creating a vacuum above it in the bottle. Had anyone actually tried this experiment they would have noticed that the water actually does not condense but expands when it freezes. For the long history of the argument see Schmitt, "Experimental Evidence for and against a Void…", 357-59.

32 Another interesting example of "copied experiments," described by Alastair C. Crombie, concerns the determination of the depth of the sea by means that were not available at the time. See Alastair C. Crombie, *Robert Grosseteste and the Origins of Experimental Science: 1100-1700* (Oxford: Clarendon Press, 1953), 24.

33 *The 'Opus Majus' of Roger Bacon,* ed. J. H. Bridges (Oxford: Clarendon Press, 1987), VI, 11: *Unde oportet primo credulitatem fieri, donec secundo sequitur experientia, ut tertio ratio comitetur. . . . Et ideo in principio debet credere his qui experti sunt, vel qui ab expertis fideliter habuerunt, nec debet reprobare veritatem propter hoc quod eam ignorat et quia ad eam non habet argumentum.*

proceed according to certain well-defined rules. As Peter King argued,[34] there was a whole genre of philosophical literature which served to establish these rules; the *obligationes* examined precisely what happens if a certain condition, *positum* is given – that is, when one can assent to or reject a sentence following from such a *positum* – even if this *positum* is, in fact, impossible.[35] Most of Buridan's arguments for and against motion in the void are, indeed, of this latter kind, that is, of reasoning *per impossibile*: the initial setting is a specific concept of void (usually the earth being annihilated while the lunar orb remained the same), and the consequences following from this setting and from the principles of the motion of elements and mixed bodies.

Buridan is, again, not the only one who uses *secundum imaginationem* demonstrations in arguing his theses. It was this kind of reasoning that John Murdoch referred to as "natural philosophy without nature,"[36] or Edward Grant as "empiricism without observation."[37] One can encounter an interesting thought-experiment even in the *Divine Comedy,* where Beatrice is arguing with Dante about the nature of the Moon:

> From such an *instance* (if you will do your part)
> you may escape by experiment (that being
> the spring that feeds the rivers of man's art.
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> Take three clear mirrors. Let two be set out
> at an equal distance from you, and a third
> between them, but further back. Now turn
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> to face them, and let someone set a light
> behind your back so that it strikes all three
> and is reflected from them to your sight.
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> Although the image from the greater distance
> is smaller than the others, you must note
> that all three shine back with an equal brilliance.[38]

There is no sign here that Dante was supposed to really perform the acts designed by Beatrice; it was enough that he *thought of* these acts and their consequences.

It is rather hard to determine what role these various kinds of experiments played in Buridan's overall argumentation. In the first question on the existence of vacuum, the thesis that void does not exist was first proposed as following from direct experience ("from such

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[34] Peter King, "Medieval Thought-Experiments: The Metamethodology of Medieval Science," in *Thought-Experiments in Science and Philosophy*, ed. T. Horowitz G. Massey (Lanham, MD: Rowman and Littlefield, 1991), 43-64.

[35] A good selection of the *obligationes* can be found in Lambert M. De Rijk, "Some Thirteenth-Century Tracts on the Game of Obligation I-III," *Vivarium* 12 (1974): 94-123, 13 (1975): 22-54 and 14 (1976): 26-42.

[36] John E. Murdoch, "The Analytic Character of Late Medieval Learning: Natural Philosophy without Nature," in *Approaches to Nature in the Middle Ages,* ed. L. D. Roberts (Binghamton: Medieval and Renaissance Texts and Studies, 1982): 171—213.

[37] Edward Grant, *A History of Natural Philosophy: From the Ancient World to the Nineteenth Century* (Cambridge: Cambridge University Press, 2007), 200.

[38] Dante Alighieri, *The Divine Comedy*, trans. John Ciardi (New York: New American Library, 2003), 609-10. (Paradiso, canto II.)

experimental induction it seems to us that there is no vacuous place"[39]), but the main arguments for this thesis mostly relied on thought experience and logical reasoning. The vacuum is imagined as a result of a certain thought experiment, although this imagination is proved to be impossible by reasons following from the concept and properties of space. The already mentioned bellows experiment and the hollow reed are used as examples supporting or illustrating Buridan's thesis, but the main reason for which the existence of void should be excluded are not these examples. In the case of condensation and rarefaction, their existence is again shown by simple observation, but their explanation is provided through logical reasoning. The experiments, like the pot with the ashes, are used as examples, often for the opposite thesis.

Generally speaking, therefore, direct observations are mostly used for proposing a thesis, while they have little role in the argumentation part of the questions. In the naturally impossible cases, direct observation was replaced by particular imaginings such as in the question on the existence of void by the divine power. Nevertheless, the use of these imaginings is rather restricted in the explanations, where the main role is played by universal logical reasoning.

II. Methodological Theory and Methodological Practice

It is a view quite commonly held by historians of science and philosophy that there was a certain inconsistency between methodological theory and practice in the Middle Ages. As Edward Grant once formulated it,

> There is a great anomaly in medieval natural philosophy. Aristotelianism was empirical and rooted in sense perception. … And yet we see very little direct observation in the questions literature on Aristotle's natural books.[40]

A similar view is held by John Murdoch[41] and by David Lindberg[42] as well. However, to elaborate on this anomaly, we should look at Buridan's methodological theory in some more detail.

Buridan, as his contemporaries in general, inherited the requirements of scientific knowledge from Aristotle. Scientific knowledge in this sense is of the necessary, therefore of the eternal; it is universal; it is demonstrated, and it involves knowledge of the causes. There are at

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39 QP fol. 73va.

40 Edward Grant, "Natural Philosophy, Theology, and Reason in the Late Middle Ages," Lecture before Department of History and Philosophy of Science, February 4, 2000. (https://scholarworks.iu.edu/dspace/bitstream/handle/2022/95/HPS%20LECTURE%202-4-2000?sequence=1, last accessed: March 14, 2011) Also expressed in Edward Grant, *A History of Natural Philosophy* (Cambridge: Cambridge University Press, 2007), 215-25.

41 John E. Murdoch, "The Analytic Character of Late Medieval Learning: Natural Philosophy without Nature," in *Approaches to Nature in the Middle Ages*, ed. L. D. Roberts (Binghamton: Medieval and Renaissance Texts and Studies, 1982), 171-213.

42 David C. Lindberg, *The Beginnings of Western Science: The European Scientific Tradition in Philosophical, Religious, and Institutional Context, Prehistory to A.D. 1450* (Chicago: The University of Chicago Press, 2007), 262-63.

least two questions that now have to be answered: what these requirements mean exactly and how they can be obtained in a generally empiricist framework ('empiricist' in the Aristotelian, and not in the British (e.g., Humean) sense).

(1) First, as Buridan makes clear in his commentary on Aristotle's *Posterior Analytics,* there are two characteristics of a scientific proposition which guarantee its necessity and eternity: Its subject needs to have a special kind of supposition (*suppositio naturalis*), while its predicate has to be predicated essentially. Essential predications are necessarily true with the presumption of the existence of the supposita of their subject, which is precisely the pre-condition taken care of by their subject having natural supposition. As Buridan makes clear,

> That is called natural supposition, according to which a common term indifferently stands for present, past, and future things.[43]

For example, the sentences "a man will be white," or "a man is sitting," do not have natural supposition, for they can be true at one time and false at another. On the contrary, the sentence "the three angles of a triangle are equal to two right angles" is not restricted to any time; it is true whenever the sentence is formed, even if in that instance no triangle exists. In this case, then, the subject needs to stand in natural supposition, otherwise, provided that according to the medieval semantic theory, the truth of a proposition presupposes the existence of its subject, this mathematical proposition could be true at one time while false at another, which is absurd.

Similarly, therefore, in demonstrative science, all propositions are true regardless of time; the sentence "every human is an animal" or "the angles of a triangle are equal to two right angles" are true even if no human beings or no triangles exist, their subjects encompassing all past, present, and future humans or triangles. This kind of supposition enables one to make a universal, necessary statement without knowing whether its subject is actually instantiated.

The other guarantor of the necessary truth of a sentence is that its predicate is predicated essentially on the subject. This criterion is needed because otherwise one could not distinguish between a definition of man as a "biped white animal" or as a "rational animal," of which only the second statement catches the essence of being human.

According to Buridan's definition, an essential predicate is one that, contrary to accidental predicates, signifies its *significata* absolutely, not in connection to anything external to it.[44] The crucial characteristic of an essential predicate is, therefore, that it can never become false of its subject unless that subject ceases to exist.

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43 *Questiones in Duos Aristotilis Libros Posteriorum Analyticorum* (hereafter 'QAnPo') I, q. 16*,* available at http://buridanica.org (last accessed: March 14, 2011): *Vocauerunt tamen suppositionem 'naturalem' secundum quam terminus communis indifferenter supponit <pro> praesentibus, praeteritis et futuris.*

44 *Summulae de Dialectica* (hereafter 'SD') 2.5.2. Translations are from John Buridan, *Summulae De Dialectica*, trans. Gyula Klima, Yale Library of Medieval Philosophy (New Haven: Yale University Press, 2001), 127.

Furthermore, what we need for an essential predication in scientific sentences is an absolute, substantial, common term, subordinated to a similar concept. Absolute terms, as opposed to connotative ones, are ones that "signify substance without any extraneous connotation."[45] Thus, for example, the term 'human' in the sentence "Socrates is human" is absolute (if Socrates ceases to be a human, he ceases to be at all), while the term 'white' in "Socrates is white" is connotative, since beside Socrates it also connotes his whiteness that does not belong to his essence. What makes essential predication more difficult is the fact that not all connotative terms *manifestly* connote something else beside their *supposita*; that is, not all connotative terms are relative terms.

Second, scientific knowledge must be demonstrated; that is, it has to proceed from first principles that are "indemonstrable because of their evidentness."[46] A demonstration, therefore, has to consist of premises that are either themselves first principles and thus evidently known, or, if they are not, they can be further resolved into the first principles.

Finally, scientific knowledge also has to involve knowledge of the causes. As Buridan notes, knowledge in the strict sense has to exclude any doubt; but if it were not knowledge of causes, then a doubt would occur about why a thing is such as it is – therefore, it could not be knowledge in the strict sense.[47] For example, proper knowledge of a lunar eclipse not only affirms that it is a lunar eclipse, but it also has to be clear about why this lunar eclipse occurs, namely, that it is the result of the Earth coming between the sun and the moon.[48]

But how can we acquire such knowledge? Can we acquire it at all, if our senses are directed to everyday objects, which are neither necessary nor universal, and which do not necessarily contain information on causal connections?

The key to Buridan's solution on the acquisition of substantial concepts is the tool of abstraction. The intellect, after conceiving and sorting out the confused sensorial data, is able to form a substantial concept from it: the confused sensory data, enables the intellect to grasp the essential characteristic of a given object.[49] That does not mean that the substantial concept is made up of the accidental concepts (as British empiricists would suggest); Buridan makes it clear that a substantial concept contains nothing else than the substance.[50] On the other hand, neither does this activity of the intellect imply that Buridan assumes some other source of knowledge apart from the

45 SD 3.1.8. Tr. Gyula Klima, 151: *[S]ignificant substantiam sine connotatione aliena.*

46 QAnPo I, q. 8: *Primum est idem quod indemonstrabile propter sui evidentiam.*

47 QAnPo I, q. 7.

48 Ibid. With this example Buridan follows a long tradition of defending the demonstration *propter quid* as the proper demonstration of science; Aquinas uses the same example when he argues that although we cannot conclude – at least in the sublunar world – to the effect from its cause, it is possible to make the inference in the other direction, from the effect to its causes. For Aquinas, see *Expositio libri Posteriorum Analyticorum* I, l. 16; II, l. 7.

49 Ibid.

50 QP I, q. 4, fol. 5 ra.

senses; the matter with which the intellect works is precisely sensory data, which, however, the senses are simply unable to analyze beyond a certain point.

It is also the process of abstraction that helps the intellect to acquire the *common* concepts, that is, concepts that indifferently signify many individuals. For example, considering the white Socrates and the white Plato, first the intellect observes that the whiteness does not belong to their substance; then, as it realizes that this whiteness is similar in both of them, it further abstracts the common concept of whiteness and humanness – a concept that is applicable to all white (or human) creatures in the world.[51]

This solution, which assumes that the intellect – from finitely many observations – is able to arrive at a true, universal concept or proposition, rests on the strong assumption that one might label as 'the intellect's natural inclination to verity:'

> Experience, deduced from many observations and memories, is nothing else than induction from singulars, through which the intellect … due to its natural inclination towards verity, concedes to a universal proposition.[52]

These universal propositions might not have the evidence of the first logical principle, but they do not even need to. What is interesting in this quote, however, is that experience *itself* already entails this universality: "experience" does not mean a single instant of sensation, but is a result of a complex process involving multiple sensations of the same object and memory. As Buridan, elaborating more on this point in his *Metaphysics* commentary, notes:

> Experience is a judgment from the memories of previously sensed similar things about another that similarly occurs. For example, if you have frequently seen some fire, and touching it you have learnt that it is hot, and so you have a memory of it, then it happens that when you see a fire, without touching it you judge that it is hot. And such a judgment is called experimental, which you gained by memory or memories that you preserved of fires that you had touched.[53]

Thus, experience, being a judgment, already presupposes − besides sensation − the active role of the intellect, and is itself in some sense universal.

Finally, Buridan's reply to the question of whether a scientific demonstration must contain causes rests on the same principle as his reply to the problem of induction. In the *Physics* commentary, he proposes some objections that would deny that demonstrations can proceed from

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51 Cf. *Questiones in libros Aristotelis De Anima secundum tertiam lecturam* III, q. 8.

52 QP I, q. 15, fol. 19 ra: *Experientia ex multis sensationibus et memoriis deducta non est aliud quam inductio in multis singularibus per quam intellectus . . . ex eius naturali inclinatione ad veritatem concedere propositionem universalem.*

53 *In Metaphysicen Aristotelis Questiones Argutissimae Magistri Ioannis Buridani* (Paris:1588, Reprint: Frankfurt a. M.: Minerva, 1964) I, q. 8, fol. 7 va: *[E]xperientia est ex multis memoriis consimilium prius sensatorum iudicare de alio simili occurrente, verbi gratia ut sepe vidisti ignem et ad tactum cognovisti illum esse calidum et de illo tu habes memoriam tunc cum occurrit tibi quod tu vides ignem et absque hoc quod tu tangas illum tu iudicas illum esse calidum; et tale iudicium vocatur experimentale quod sit tibi per memoriam vel memorias quas alias retinuisti de ignibus quod alias tetigisti.*

causes, and that knowledge of causes is altogether possible.[54] The most important of them probably derives from Autrecourt;[55] if there are two distinct things, *a* and *b,* then it is impossible to infer the existence of *b* from the existence of *a*: If they are really distinct, God can maintain one while the other is destroyed, so the existence of one without the other does not entail a logical contradiction. Therefore, if we know that *a* exists, but nothing else, we can be never sure that *b* also exists. Now, causes and effects are distinct things; the cause does not contain its effect nor vice versa. In this case, however, one can never infer the existence of the effect from the existence of the cause, or the existence of the cause from that of the effect.[56]

In his answer, Buridan again refutes the claim that every demonstration should be reducible to the first logical principle.[57] Thus, it is not impossible for the intellect to arrive at some knowledge of *b* from the knowledge of *a*, even if *a* and *b* are distinct entities; to use Buridan's own example, if one sees a man one can conclude that he has a heart, even if one does not see it directly. For we know – it is demonstrable – that a man cannot live without heart, while the minor premise, that the man lives, is evident from the senses.[58] It means that the knowledge of causes does not directly derive from sensory experience, but its source is an inference made by the intellect.

Thus, with his elaboration on the problem of the knowledge of causes, of the acquisition of substantial concepts and of the formation of universal scientific statements, Buridan can be said to have successfully argued for the possibility of scientific knowledge in the Aristotelian sense. Our intellect is able to acquire some information about the essences of things from which the necessary and universal scientific propositions can be formed, given that the intellect, with its natural inclination toward verity, can generalize the acquired substantial concepts without losing their evidentness. This evidentness is not the same as that of the first logical principle, but it is enough for the natural sciences. We can also acquire knowledge of causes, since – in this weaker degree of evidence – we can infer the existence of one thing from the existence of another. Buridan's solution concerning universal knowledge as well as the knowledge of causes, however, rests on the principle of the intellect's natural inclination toward verity, which, however, can hardly be demonstrated within this framework.

Consequently, the role of sensory experience in Buridan's theory of science is twofold. First, there is a group of principles that can only be acquired by experience; they form the basis of scientific reasoning. On the other hand, however, the senses' preeminent role must be understood

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54 The *questio* is in QP I, q. 4.

55 Whether Autrecourt was really the target of Buridan's arguments here and elsewhere, can neither be proved nor disproved sufficiently. The former was attempted byJack Zupko, "Buridan and Skepticism," *Journal of the History of Philosophy* 31 (1993): 191—221, while the latter was argued by Johannes M. M. H. Thijssen, "John Buridan and Nicholas of Autrecourt on Causality and Induction," *Traditio* 43 (1987): 237—55.

56 QP I, q. 4, fol. 4 vb.

57 QP I, q. 4, fol. 5 vb.

58 QP I, q. 4, fol. 6 ra.

with certain restrictions even in the case of concept acquisition. First, the assent to or dissent from a certain sense experience is always given by the intellect; it is the latter that can judge whether the disposition of the senses or the medium is adequate enough for providing reliable information. Second, the acquisition of substantial concepts, although originating from sensory experience, is again carried out by the intellect. It is the former which provides sufficient data, but it is the latter that can grasp the essential characteristic of a given object. Finally, it is also the intellect's task to concede to a universal proposition by induction from the singular instances and to arrive at the knowledge of causes when only the effect is known.

It is not an accidental feature, therefore, that scientific reasoning – which, by definition, has to be universal and an explanation of causes – does not proceed primarily from experience. As we have seen, experience did play an important role in the formation of Buridan's theories, but not in their demonstration and causal explanation; thus, it corresponds precisely to the twofold role of sensory experience in the formation of scientific propositions. For although it is sensory experience that provides the basis of our cognition, it alone cannot produce scientific concepts and even less scientific explanations. Therefore, the – in certain respects restricted – role of experience in Buridan's scientific practice, instead of contradicting, seems rather to directly follow from his methodological theory; experience, indeed, cannot be given more weight in scientific explanations unless the fundamental scientific question ceases to be a question about causes.