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Reduction for Historians of Science

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The reductive strategies, such as the deductive-nomological (DN) model of explanation, or the Nagel–Schaffner reduction, have been perceived negatively ever since their first applications in historical inquiry. However, the role of the analysis of inter-theory relations, such as the preservation of success and retrospective rationality, has hardly ever received much attention from historians of science. In this paper, I am exploring the applicability of the analysis of inter-theory relations for the rational reconstruction of the development of science. I demonstrate that the historiography of Anneliese Maier is a good example of a few reductive strategies at play in historical inquiry that do not submit to the same criticism that the synchronic reductive analysis of theories is submitted to.

Keywords: diachronic reduction, history of science, rational reconstruction, Anneliese Maier, Nicolo Oresme

INTRODUCTION

To achieve a postulational and ontological economy across disciplines philosophers of the 20th century have been developing ways of explaining one theory by another. They have been aiming to achieve that with certainty and without any logical inconsistencies. To establish such a relation means to establish theory reduction. Even though the establishment of philosophy of history as a separate branch of philosophy could in part be attributed to the issue of theory reduction, the general reductive models had undergone harsh criticism from historians. Until this day, the attention that is paid to reduction is the negative one. Nevertheless, it is only focused on either the deductive-nomological (DN) model of explanation (Hempel, Oppenheim 1958), or on the Nagel (1961) – Schaffner (1967) reduction. Recently, P. Roth has developed an anti-reductivist account to historical explanation, based on the same negative attitude towards reductionism in history (Roth 2020). However, there are more than two roles of reduction in science, and some of them – we will try to prove – are worthy of a more positive outlook.

The value of the alternative account to reduction for the historiography is rarely ever discussed. This alternative notion is called the successional or the diachronic reduction and has been developed by Nickles (1973), Wimsatt (2006), Rosenberg (2006), Dizadji-Bahmani et al. (2010), van Riel and Van Gulick (2016), and others. In this case, to establish theory reduction no longer means to express a logical relation between the branches of different disciplines, nor that diachronic reductions are ontological reductions. Generally, the aim of the diachronic reduction is taken to be the achievement of the justification (or the heuristic guidance) of the present science by the preceding theories (Nickles 1973: 185).

In this paper, I explore how synchronic reduction is different from the diachronic one in the historiography of science. And I showcase the historiography of the famous medievalist Anneliese Maier as a good example of the diachronic reduction at play. It is not a revolutionary historiography, it employs long-term norms in the explanation of the scientific change, and it is focused on how the Aristotelian natural philosophy justified and heuristically guided the succeeding Galileo's natural philosophy.

SYNCHRONIC AND DIACHRONIC REDUCTION IN HISTORICAL INQUIRY

Synchronic Reduction

The notion of reduction was brought to historiography from logical positivism. The main issues with regards to the establishment of reduction in history were in line with the general philosophy of science literature of that time. In the classic papers, such as Hempel's 'The Function of General Laws in History' (1942), or Nagel's chapter 'Problems in the Logic of Historical Inquiry' (1961), the notion of the covering laws firstly employed in ethics or psychology was implied in historical explanation. The covering laws are either statistically or universally established generalisations that govern the relevant evidence. The function of these laws is to connect the events in patterns and thus provide a causal explanation to them. All the explanations, predictions, interpretations, and judgments of reference that historians make are taken from various fields of scientific research either explicitly or tacitly (Hempel 1942: 47). Thus, the explanations in history rest on the physical, biological, chemical, and other regularities.

By appealing to these laws historians should be able to establish the truth-value to their narratives (to justify them). Otherwise, their explanations of sequentially ordered events should not be called other than explanatory sketches. As Nagel puts it, historians are rarely mere archivists and collectors of documents. They often seek to explain the events that they record in terms of causes and consequences. But they do not profess an ability to apprehend causal connections between single occurrences by way of some direct, infallible intuition of such connections. To meet these tasks 'historians must be armed with a wide assortment of general laws, some of which are undoubtedly accepted tacitly as "common-sense knowledge" while others are adopted because they are endorsed by some natural or social science' (Nagel 1961: 549–550).

This model of reduction, often referred to the Hempelian and Nagel–Schaffner reduction, seems to have had the most influence on how we understand the epistemic value of the historical narrative today. Only recently P. Roth (2020) has reconstructed the structure of historical narrative as a form of scientific explanation that is independent of any such generalisations and the hierarchical organisation of science. However, it was also established by only reflecting upon the reduction understood in the first sense – as a relation between the already established theories. Other roles that reduction plays in historical sciences are left rather unexplored, and therefore uncriticised.

However, the doctrine of emergence (also called holism) raises issues that the synchronic analysis cannot deal with. There are disciplines, such as economics, ethnography or anthropology, that neither imply simplicity nor are they analysable by inference relations (provability of sentences or their deducibility from other sentences). The characterisation of reduction, as a deductive explanation of one theory by another, will not fit to account for the historically succeeding theories very well. It only gives us a picture of our current science

as a consolidated, efficient conceptual scheme, from which the older scientific theories can be derived. In other words, the older theories would be understood as the logical consequences of the current theories that there must have been superfluous postulates in the older theory, that by deduction can be demonstrated as derivable from other – more fundamental postulates. Consequentially, only the more fundamental postulates should be part of the newer theories. However, such analysis says rather little about the actual demise of one theory and the takeover of the other – it does not explain their development. It is wide in form but narrow in content. Thus, it is relevant only for metaphysicians who are concerned with the ontological economy of theories or the unification of science, rather than the practitioners of science who turn to history in search of particularities in theories at the time of their formation.

Diachronic Reduction

Moreover, we should have in mind that the construction of complex narratives that encompass conceptual changes is an ordinary task for historians of philosophy and science. Historians' work often exceeds the construction of causal statements within the conceptual framework, and often gives shape to conceptually complex and incompatible phenomena. It is nonetheless problematic to reconcile the history of science as a result of contingent and ever-changing circumstances and contexts, and as a discipline, that supposedly produces trans-historically valid results. That is why whenever the historian of science tries to explain the dramatic narratives, the requirement to produce justifiable results should not be dropped. The causal analysis alone cannot suffice in achieving this goal. Instead of it, the analysis of inter-theory relations should be pursued.

The problem of reconciling the history of research with the trans-historical validity of its results has been addressed by L. Krüger (1980). His findings amount to the thesis that inter-theory relations function both within (long-term) norms of scientific research, and as indispensable tools for the rational reconstruction of scientific development (Pearce, Rantala 1984: 347). The analysis of the theories need not result in the total reduction to the most fundamental theory, there is an entire spectrum of distinguishable, variously connected relations, 'the analysis of which is indispensable for an adequate description of our present knowledge as well as for a satisfactory understanding of its justification' (Krüger 1980: 96). Historians who try to make sense of the conceptual changes across revolutionary steps of theory formation have to investigate what restrictions and what resources of justification for the formation of new theories were provided by the previous theory. This is done in relation to the norms of research whose existence is postulated, and where the rules of the justification of one theory by another belong. But without which a long-term continuity of the scientific development would be incomprehensible.

The development of new ideas is heuristically guided by the predecessor theories as the new ideas are often justified by showing that they bear a certain relation to the predecessor theory. In this sense, the reduction is domain preserving. It demonstrates that the successor theory adequately accounts for phenomena in the domain inherited from its successful predecessor. Moreover, it does not grant the opposite relation, where the succeeding theory would be derived from the preceding one by combining the already established content of the theories and eliminating everything that is unsuccessful or overflowing and ultimately relating the reduced (predecessor) theory to the universal laws.

Instead of reducing historical phenomena to causal explanation, hoping this procedure would make history more scientific, reduction could prove to be beneficial in assessing

conceptual change and accounting for theoretical continuity. It is surprising that explanatory reduction, which deals with justification of sentences, receives so much attention from historians of science and philosophy: 'Analytical philosophy of history, for the twenty-five years following Hempel's article, by and large consists in critiques or defenses of the applicability of this model of historical explanation (Roth 2020: 4), while the prospects of establishing the diachronic reduction in historical research remain overlooked, but are more relevant for historical research and are more wide-ranging than the explanatory reductions.

AGAINST THE REVOLUTIONARY READING OF ANNELIESE MAIER'S HISTORIOGRAPHY

Instead of considering the analysis of the structure of historical explanation as the main feature of reductivism, the analysis of inter-theory relations could be employed in the historiography of science.

The question of the relationship between late scholastic natural philosophy and the classical physics of the 17th century was highly debated in the first half of the 20th century. It was agreed that Late Medieval natural philosophy played an important part in the development of Early Modern science. Still, it was not agreed to what extent was that part significant. One of the suggestions was that the achievements of the 14th-century natural philosophy had largely anticipated the theories of later classical mechanics (Duhem 1984 [1913]: 582–583).[1] Another one was that the importance of Late Medieval philosophy for the classical mechanics was not in the actual achievements, but in the new attitude toward nature[2] (Maier 1936: 146).

Duhem studied Oresme's method of graphical representation and concluded that it had anticipated Descartes's analytic geometry (Duhem 1984 [1913]: 384–385). On the contrary, Maier concluded that it had not.

According to Maier, taking the wider context into consideration, we will rather see that many steps to anticipate the birth of classical mechanics could have been taken at the time of Oresme, but they were not. According to Maier, the method of graphical representation associated with N. Oresme was developed and systematically applied in the 14th century, it provided clearer means of demonstrating theories concerning quantitative relationships, thus it survived into the succeeding centuries. Nevertheless, Oresme (and others) never 'extended their knowledge into other, more general fields by means of calculations' (Maier 1936: 152). Thus, although Oresme and other Late Medieval thinkers often arrived at 'astonishing and seemingly modern insights', the newly discovered methods were not exploited widely enough (1936: 147). According to Maier, the scientific developments remained within the general framework of the time, and new directions in the study of nature were not pursued.

Maier's work has been significantly criticised over this explanation. According to Ariew and Barker (AB, hereafter) (1992) Maier judged Medieval thought and Early Modern science to be incompatible because of two prevailing themes in her work:

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[1] This proposition is primarily known as Duhem's continuity thesis. According to W. A. Wallace, the continuity thesis is a composition of two daring statements. Firstly, the condemnations of 1277 marked the origin of modern science, the decisive break with Aristotle and the beginning of new, imaginative cosmologies to replace his; secondly, the 14th-century development following the condemnations gave birth to important new concepts, such as impetus and uniformity difform motion (Wallace 1981: 303).

[2] 'What changes is the method of knowing nature. The attempt is made for the first time to find principles that permit a direct, individual, and empirical perception and understanding of nature, independent of all authority' (Maier 1938: 147).

Two themes divide the historical writings of Koyré and Maier from Duhem. Both authors present histories of science in which metaphysics plays a primary role in explaining scientific change. Second, the role of metaphysics in science underpins a historiography of Early Modern science that gives central place to the concept of revolution. Medieval thought and Early Modern science are judged to be different in kind as well as in content. To the extent that Maier and Koyré project these concerns into Duhem's work, they fail to make contact with Duhem as a historical figure or with his contribution to the history and philosophy of science (Ariew, Barker 1992: 330–331).

We argue that their criticism disregarded Maier's historiography on both points.

Firstly, they claim that to support her revolutionary reading of the origins of modern science Maier holds that metaphysics provides a needed foundation for the content of empirical science. And she also claims that since Early Modern metaphysics is discontinuous with Medieval metaphysics, the Early Modern science cannot be continuous with medieval thought either (1992: 333). To support their claim, the authors quote a passage from Maier's *On the Threshold of Exact Science*: 'The attempt is made for the first time to find principles that permit a direct, individual, and empirical perception and understanding of nature, independent of all authority' (Maier 1936: 146–147). From this, they conclude that Maier's criticism of Duhem fails 'unless he also accepts the thesis that metaphysics forms the foundation of empirical science at every period in its history' (Ariew, Barker 1992: 334). But from this quote, we can only state that Maier was indeed very attentive to the metaphysical underpinnings of medieval and modern thought. To claim anything further, e.g. that the shift from one metaphysical system to another explains the shift in scientific theories altogether is a much more complex point to make, and AB do not follow through with it.

On the contrary, if the revolutionary reading of the historiography was accurate, which AB try to imply, there could be no correspondence or transmission between the theories to talk about. It was the point of AB's criticism that the scientific revolutions change the content of the theories and the metaphysical foundations of the theories. Thus, there is no way to account for the truth-likeness of the ideas. It would be incoherent if Maier actually tried to account for both, the revolutionary change and the long-term truth-likeness of the theories. And according to them, this was her intention: 'If one believes that metaphysical changes have long-term implications for science, how can scientific opinion be unanimous over the long term? This is a question that Koyré and Maier cannot answer, despite their belief in scientific progress'[3] (Ariew, Barker 1992: 337). For this reason, it is not quite accurate to attribute a revolutionary reading of the history of natural science to Maier. Such a reading makes it

[3] While we do not argue with the fact that Maier is probably an advocate for scientific progress, we do not think that Ariew and Barker had argued for it sufficiently enough. They introduced this idea by providing reference to three different passages from her different essays. But nowhere in these passages she explicitly states her position about such a view. They refer to pages 63, 75 and 170, where Maier's belief in scientific progress is presumably expressed. But at best the passages are only about what made exact natural science possible, or how wrong was an ancient idea from the standpoint of modern physics, or what steps would have led from a purely philosophical view of nature to exact science. Without a coherent explanation of Maier's beliefs about the truth-likeness of science, it remains only implicit that she believes in the progress of science. Indeed, scientific progress is coherent with the notion of the ahistorical validity of scientific knowledge, and not coherent with the notion of revolutionary change in science. However, it should be explained more deliberately than how was it done in AB's paper. One cannot impose the notion of progress on a historian simply because they constantly refer to the evidence-based course that the history of science had actually taken. The implication that historical theories stand in a relation to the truth about the world has to enter into the picture (Psillos 1999: xv).

complicated to talk about the transitions and long-term ideas and norms that surfaced in the early modern thought despite the shift in metaphysics – issues to which she had paid so much attention.

The work by A. Maier could be seen as an exemplary case to show how an inquiry into the inter-theory relations of two successive scientific theories helps represent the intellectual context of the period often called the birth of Early Modern science and to provide an inherently coherent explanation of the theory-change that took place in that time. But for this, the revolutionary reading of her historiography must be dropped.

Thus, I will further elaborate on the idea that (with regards to the scientific change) Maier's historiography is practice-based reductivist historiography.

THE DIACHRONIC REDUCTION IN HISTORICAL PRACTICE

We will prove that Maier's work is an example of the diachronic reduction at play on two points.

In historical disciplines claims explaining the succession of historical events as causal are always met with struggle. How is it that the historian acquired the knowledge of causal relations in history? Moreover, how do they justify these relations? Does the way how the causal claims were justified grant scientific value to the descriptions of historical processes?

As for the establishment of the causal link, the situation that Maier deals with is such that from the perspective of later mechanics, there were developments that were supposed to take place, but they actually did not, that is why the 14th-century mechanics cannot be called anticipation of the early modern mechanics. Her explanation is that the granting of Aristotelian authority was the main cause of why the 14th-century physics did not exhaust its potential. Thus, she is dealing with a unique event, in need of a thorough comprehension of the functioning of norms, rules and laws in a certain paradigm, in order to pose it as a claim against Duhem's interpretation of the same event. And it is by the analysis of these practices and norms of inquiry that she arrived at the conclusion.

Nevertheless, the elaborate historical knowledge about the period, the in-depth inquiry into the practices and the intellectual context in the 14th century universities do not grant that Maier's causal claim is true or likely to be true. There is a need for a separate justification of the causal claims about historical phenomena. Moreover, if the causes of the shift in science are determined by arguments that do not belong in the scientific method, in our case, by the norms of the inquiry in nature that were present in the 14th century, and it was necessary that the norms stopped playing part in order to develop the principles of natural inquiry any further, then the rational reconstruction is limited to the paradigmatic cases or the so-called normal science. Following the analysis of the practices and norms established in a particular paradigm (e.g. within the Aristotelian metaphysical system) to indicate what constituted certain scientific theories leads historiographers to adopt the view that the change in science is only a chain of alternative attempts of dealing with nature that has appeared in different points in the history of science (Krüger 1980: 93). In principle, these theories would be regarded as equally legitimate competitors for what we call knowledge. And while it is true that by the analysis of the structure of scientific theories we cannot predict their development, by only looking at the norms and rules that were followed in scientific communities, we cannot coherently understand the overall development of the theories either. We would only develop a fragmentary understanding of the particular theories, without knowing how they enter into our present understanding of the science. Instead, we need the tools to show that even

the breaks of normal tradition can be explained as a piece of rational action (Krüger 1980: 95). In particular, we could only define why it was rational for the natural philosophers that worked within the Aristotelian framework to stop criticising his doctrines at a certain point. What we cannot do by the paradigmatic (or fragmentary) reconstruction of the development of science, is to explain why and how a consensus among the Early modern natural scientists about, say, the mathematical representation of qualities was finally achieved after the break from the Aristotelian tradition.

Maier's historiography is not, however, part of the fragmentary explanation of a period in the history of science. The development of methodology, or, as she explains it, the means of knowing nature, was considered among the rules of inquiry that were taken over into the 17th century. Maier explains that the innovation of the fourteenth-century thinkers consists in 'systematically pursuing on a very broad front the elaboration and development of a true methodology, one that survived until the time of Galileo and Descartes' (Maier 1936: 150). Thus, despite the fact that the developments of the actual ideas that were necessary to anticipate the Early modern science did not take place in the 14th century, the development of the method of inquiry into nature played the role of the norm that bridged the supposed gap and determined the research steps taken later. Maier employs an integrated view of the development of science, instead of the fragmentary one. This is possible only because of the attention that is paid to the norms of research that did not vanish with the Aristotelian natural philosophy.

Our second point is that there are many ways how to draw the relation between the Aristotelian philosophy and the 17th-century natural science, rather than just to indicate a single logical relation between the two theories. Maier is especially peculiar about disclosing the variety of those ways. If a single relation between the theories were held, then the reduction of predecessor theories by their successors would amount to the explanation of the earlier theory by the later one. Thus the role of reduction would be strictly explanatory. But because to make her point about why the Late Medieval natural philosophy cannot be called the anticipation of the Early modern science, she considered how the 14th-century ideas might have corresponded with the later ones. From various such correspondences, a reductive relation between the Aristotelian natural philosophy (understood as a theory) and the Early modern scientific theory might be established.

In particular, Oresme's coordinates were not an anticipation of the geometry, nevertheless, the new manner of visualising was for the first time systematically employed. It provided clearer means of demonstrating the newly developed theories concerning quantitative relationships. Thus Descartes's analytic geometry corresponds to Oresme's method of graphical representation with regard to the long-term norms, that in this case were the means of knowing nature. Considering more such correspondences, such as Buridan's impetus and Galilei's inertia, the infinity of time, the solutions to physical problems by calculations, etc. Maier tracks key principles used by the old theory that also had appeared in the new one. That is why her approach to the history of science is a reductive one.

Finally, the roles that the reduction plays in Maier's historiography are multiple. For example, at least it is shown how the success is preserved between the new (N) and the old (O) theory. O, from the perspective of N, is (to some degree) incorrect, yet it is successful by virtue of being compatible with N in the relevant domain – which, in this case, is the entire domain of success of O (Crowther 2020: 15). Or, reduction is useful for the retrospective rationality, where the new theory (N) is held to explain why the old one (O) is as successful as it is, in

order to maintain the impression of scientific progress, and the connection between a theory's being successful and it is being approximately correct.

CONCLUSIONS

Reduction in the first half of the 20th century was understood as an agenda problematising the status of history as a scientific discipline. Until this day, the discussions about reductivism that involve historians of science and philosophy still express this negative attitude. Nevertheless, we can find examples of how studying the relations between the succeeding theories is a valuable tool to make sense of scientific change. We showcased Anneliese Maier as an exemplary historian employing this approach.

However, the positive outlook towards reductivism is more viable from the diachronic reduction point-of-view. In that case different theories are understood as developing classes of statements and the relations between them involve multiple weak correspondences that have played varied roles in the development of science. Among many roles the preservation of success and the retrospective rationality are the key roles in accounting for the scientific status of causal claims in the history of science. By means of reduction, theories could be linked in an inherently coherent way even in the situations where historians deal with unique events, base their causal claims on counterfactuals, and the periods they deal with involve dramatic narratives. The works of Anneliese Maier are the exemplary cases of dealing with such circumstances.

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Redukcijos reikšmė mokslo istorikams

Santrauka

Praeities tyrimuose bendrieji redukcijos modeliai dažniausiai yra vertinami neigiamai. Nuo pat tokių reduktyvistinių strategijų, kaip dedukcinis nomologinis (DN) priežastinio paaiškinimo modelis arba Nagelio-Schaffnerio redukcija, taikymo istoriografijoje pradžios sulaukta nemažai kritikos. Šiandien reduktyvizmu kaip istoriografijos metodu nelabai domimasi. Tačiau ši kritika apsiriboja tik sinchroniniais teorijų struktūros aspektais. Tai, kokia yra redukcijos reikšmė mokslo raidos rekonstravimui, beveik netyrinėta. Šiame straipsnyje siekiu ištirti, kaip mokslo raidos rekonstrukcijoje taikoma tarpteorinių ryšių analizė. Aš pademonstruoju, kad medievistės Anneliese Maier istoriografija yra geras tokios redukcijos pavyzdys. Jos istoriniam tyrimui negalioja tokia pati kritika, kokia išreiškiama sinchroninei reduktyviai analizei istoriografijoje.

Raktažodžiai: diachroninė redukcija, mokslo istorija, racionali rekonstrukcija, Anneliese Maier, Nicolo Oresme