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Ian Hacking – Special Issue

What is a Style of Reasoning?

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Abstract:

In this paper I propose a solution to the crucial issue of the number of styles of reasoning. Ever since, in the 1980s, Ian Hacking outlined what he later called the 'project of styles of scientific reasoning', for short the 'styles project', he has never provided criteria for individuating styles of reasoning. Whether or not certain ways of thinking can be counted as styles of reasoning in the sense of Hacking is a question that has remained unanswered, despite its apparent relevance to various other controversial issues related to the styles project. I shall frame the issue within a view of categorization which begins with the later philosophy of Wittgenstein and culminates with the so-called theory of prototypes in psychological research. My conclusion will be that there is no clear boundary to the category of styles of reasoning and that degrees of category membership for a given way of thinking are determined by its degree of similarity to prototypes such as the statistical style of reasoning.

Keywords: Ian Hacking; Styles of Reasoning; Historical Epistemology; Family Resemblances; Theory of Prototypes

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Introduction

I wish to discuss an issue concerning the characterization of the notion of 'style of reasoning', one of the most important analytical frameworks in the history and philosophy of science. Hacking encountered the idea of style in 1978, at a conference in which the historian of science Alistair Crombie (1915-1996) lectured on what he called 'styles of scientific thinking in the European tradition' (Crombie 1978). The latter listed six major styles of argumentation or, as he conceived them, six *methods* of scientific enquiry central in the Western scientific thought: the *postulational style* (exemplified by the Greek geometry), the *experimental style* (based on the use of experiment to control postulation and explore by observation), the *style of hypothetical modelling* (the hypothetical construction of analogical models in order to explain unknown properties of phenomena), the *taxonomic style* (the ordering of variety by comparison and taxonomy), the *statistical style* (the statistical analysis of regularities of

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populations), the *historico-genetic style* (a way of explaining the present as a development of the past regulated by certain laws).

Although Hacking proposed some changes in Crombie's list, e.g. in their sequence and specific trajectory in time, he did not reject it. However, as I shall explain in the next section, over time Hacking himself and several other scholars described many other ways of thinking, some of which have played a crucial role in the history of scientific thought, claiming that they should be counted as 'styles of reasoning'. As a consequence, the issue arose of having to distinguish what can be considered a style of reasoning and what cannot. This is not an abstract question with no bearing on the assessment of the entire styles project. Indeed, on the one hand, should we exclude one of the ways of thinking presented, we might inevitably end up with a partial account of scientific thinking. On the other hand, should we accept certain candidates for being identified as styles of reasoning, we might end up with an inaccurate account. And what is more, by allowing the proliferation of the number of styles we might remove all meaning from the notion of style of reasoning and negate Hacking's original purpose of employing it to describe how and why certain concepts, questions and sentences come to be shared and discussed (cf. (Sciortino 2021)). Furthermore, as we shall see in the next section, whether or not the style project implies epistemic relativism may also depend on what counts as style of reasoning.

So far, no solution to this issue of individuating styles of reasoning has ever been proposed in the literature, although scholars such as Martin Kusch have acknowledged the issue. The latter wrote that 'Hacking has failed to make progress as far as criteria are concerned' (Kusch 2010, 170) and that Hacking has taken different lines concerning the issue of the number of styles: 'sometimes he writes as if Crombie's list were definitive, sometimes he adds the laboratory style, sometimes he leaves open the possibility that any number of further styles might be discovered' (Kusch 2010, 170). However, Kusch did not undertake the task of offering convincing criteria for identifying styles of reasoning and neither did Jean Gayon when he explained how Hacking's use of the term differs from other uses in literature (Gayon 1996).

One of the upshots of this paper will be that it is a mistake to think that there should be necessary and sufficient conditions for being a style of reasoning. If anything, it might also wrong to suppose that Hacking ever had this goal. We must not be misled by the fact that Hacking is a philosopher trained in the analytic tradition. In his works, the logical techniques of the North-American school are deliberately combined with historical instruments of the French school (Brenner 2006). The styles project itself reflects a certain style of philosophical thinking that does not embody a perspective based on logic, which characterizes other areas of Hacking's research, where reasoning is ensured by stable prescribed definitions. To better clarify this point let me first provide an over-simple classification into four major areas of Hacking's philosophical contributions, of which I will give a brief description below: (a) logic and philosophy of probability; (b) historical epistemology; (c) general philosophy of science; and (d) study of 'human kinds'.

(a) Logic and Philosophy of Probability

Hacking's first book was entitled *The Logic of Statistical Inference* (2016 [1965]) -- it is an analysis, from a point of view of a logician, of the patterns of statistical inference. A significant result of this study was that the Neyman-Pearson theory of testing statistical hypotheses is flawed and, in the domain in which is valid, it is included in the likelihood theory. Two years later, Hacking provided another important contribution to the field of philosophy of probability, when he published the paper 'Slightly more realistic personal probability' (1967). Bayesianism maintains that evidence *e* supports hypothesis K if Prob(K/e) is larger than Prob(K). Hacking noted that this claim rests on the assumption that an agent ought to

change beliefs by conditionalization and criticised the so-called Dutch book argument used to justify this assumption.

(b) Historical Epistemology

In addition to work in the tradition of analytic philosophy, Hacking has made important contributions to the field of historical epistemology. The latter is a tradition of philosophy of science born in France at the beginning of the twentieth-century which tries to reconstruct the historically situated conditions of scientific concepts. Since Hacking's *The Emergence of Probability* (2006 [1975]) identified the intellectual transformations that made the concept of probability possible in the seventeenth century, it can in all respects be considered as a work of historical epistemology. In that book, Hacking applied that kind of analysis that Foucault called 'archaeology', which tries to uncover the hidden rules that restrict the range of thought (Hacking 2006b, 3) (see also (Martínez Rodríguez 2021) and (Sciortino 2023c)). The companion book to *The Emergence of Probability*, i.e. *The Taming of Chance* (2008 [1990]), continued the same archaeological inquiry by showing the intellectual and social changes that the coming into being of a certain organization of probabilistic concepts produced.

The point that seems essential to me here is that, as I shall explain in the next section, these two works can be regarded as a comprehensive description and explanation of the 'statistical style of reasoning'. However, this label explicitly appeared only in *The Taming of Chance* (1992), in which Hacking wrote that his topic is one of the six styles in Crombie's list, i.e. 'the statistical analysis regularities of populations', and in the paper 'Statistical Language, Statistical Truth and Statistical reason' (Hacking 1992b). The inquiry contained in *The Emergence of Probability* can be read as an account of the birth of the statistical style of reasoning only with hindsight. Indeed, Hacking started to elaborate on the notion of style three years later the publication of this book. In as much as styles of reasoning represent the answer to the question of what made certain propositions objective, Hacking's style project falls into the field of historical epistemology (cf. (Kusch 2010) and (Sciortino 2017, 2023b)).

(c) General Philosophy of Science

In the book *Representing and Intervening* (1983b), and a number of articles, Hacking claimed that regular manipulation is the strongest evidence for the existence of an unobservable entity -- 'if we can spray them, they are real' (Hacking 1983b, 22), as he famously wrote. He described himself as an *entity realist*: an anti-realist about theories and a realist about entities (Hacking 1983b, 37). Among other contributions to the general philosophy of science, Hacking deserves credit for having explored the contingency issue, especially in his last book *Why is there a Philosophy of Mathematics at all?* (Hacking 2014). This is an idea that appeared in embryonic form in Fleck (Fleck 1979 [1935]) and gained momentum with the advent of social constructionism. Hacking framed the issue in *The Social Construction of What?* (1999b) and developed it with some variations in (Hacking 2000, 2014) on the basis of ideas expressed also in (Hacking 1988b, 1992a, 1996a) and later in (Hacking 2005).

(d) Study of 'Human Kinds'

Hacking has written about this topic on and off for about thirty years. A central point of his project is that the act of classifying opens up to the classified person a new possibility of being human which can even motivate a revision of the classification. Thus, there is a mutual interdependence between classifications and people classified. In articles such as "Making Up People" (Hacking 1986) and 'The looping effects of Human Kinds' (Hacking 1996c), Hacking introduced the notion of 'human kind' and showed how classificatory

practices legitimize new kinds of being making. The books *Rewriting the Soul* (1995) and *Mad Travellers* (1998) applied these ideas to mid-twentieth-century multiple personality disorder and late-nineteenth-century travelling amnesiacs.

The areas of historical epistemology (*b)* and human kinds (*d)*) are expression of ways of doing philosophy that are different from that adopted in the area of logic and philosophy of probability (*a)*). Whereas the contributions in area *a)* consider concepts such as probability, statistical thinking, proof, evidence and the like as timeless and permanent, those in area (*b)* start from the opposite presupposition -- 'they [these concepts] change, evolve, undergo mutations, emerge out of new practices or radical transformations of old ones' (Hacking 1999a). More importantly, as I shall explain in section four, in area *d)* Hacking considered certain concepts not as categories *defined* by the common properties of its members but as categories represented by best examples. I believe this is the right perspective to adopt in dealing with the issue of the characterization of styles of reasoning -- it is in area *d)* rather than in area *a)* that one has to search for the solution.

In the next section, I shall summarise the fundamental theses of the styles project and I shall identify six properties of the *statistical* style of reasoning. In the third section, I shall spell out the issue of the characterization of styles. In the fourth section, I shall address the issue from the perspective of a theory according to which categories have best examples (prototypes) but are not defined by a set of properties common to all the members (classical view). What I shall seek to show is that a style of reasoning can be regarded as a member of a category of which a prototype is the statistical style of reasoning. I shall also draw the diagram of the category of styles of reasoning in which different members belong to concentric circles. The styles in Crombie's list will occupy the innermost circle of the 'best examples'.

The Styles Project

Ian Hacking's Proposal

The styles project is a set of ideas and suggestions, put forward in various works of Hacking (Hacking 1982, 1992c, 1983a, 1992b, 1995a, 2002a, 2004, 2009) which should be understood as a programme of research (Hacking 2012) rather than a full-fledged theory. A clear point that emerges from the 1982 paper 'Language, Truth and Reason' is that, despite Hacking's admission that Crombie has been the starting point of his project, their enterprises must be regarded as entirely different. This is not only because the former used the historiographical notion of the latter to launch a *philosophical* project, but also because the two had different visions of history. In 2009 Hacking wrote that, while Crombie favoured continuity, his instinct was 'exactly the opposite' (Hacking 2009, 14). 'I have a revolutionary temper', he had written three years earlier, 'perhaps under the excessive influence of Bachelard, Kuhn and Foucault […] I am interested in ruptures that radically transform our methods of reasoning' (Hacking 2006e, 9). More than this philosophical instinct it was his Foucauldian study on probability and his ideas about the Scientific Revolution that convinced him that styles have clear beginnings (Hacking 1991, 2009, 2012, 2006 [1975], 2007, 2006d): 'I like to tell the history of each style as having at least one sharp moment of crystallization, a fixing of how to go in the future' he wrote (Hacking 2009, 14).

Beside the suggestion that styles have sharp beginnings, he made other claims:

Every style of reasoning introduces a great many novelties including new types of:

Objects

Evidence

Sentences, new ways of being a candidate for truth or falsehood

Laws, or at any rate modalities

Possibilities

One will also notice, on occasion, new types of classifications and explanations (Hacking 2002 [1992], 189) (see also Hacking 1995a, 75) .

To clarify, Hacking claimed that a style introduces new types of objects (e.g. the "abstract objects" of the geometrical style, i.e. straight points, lines and planes) in addition to new standards of evidence, laws, possibilities and new true-or-false sentences, i.e. sentences whose truth-value hinges on the style itself (for this reason they are called *style-dependent sentences*). In particular, according to him, whether or not a proposition possesses a truth-value depends on whether we have ways to reason about it – styles emerge in particular historical periods and determine what counts as rational or irrational.

Hacking also added that:

> Styles become standards of objectivity because they get at the truth. But a sentence of that kind [i.e. a style-dependent sentence] is a candidate for truth or falsehood only in the context of the style. Thus styles are in a certain sense 'self-authenticating' (Hacking 2002 [1992], 191).

'Self-authenticating' (Hacking 1982, 1983a, 1988a, 1991, 1992a, c, b, 2009, 2012, 2007) is a term that refers to the circularity induced by the following double claim: the truth of certain sentences is what we find by using a style; in turn, a style is a standard of objectivity because it gets at the truth. Hacking's views about styles evolved over the years: in recent papers, he put emphasis on the idea that a style is a way of thinking *and* a way of *doing*, i.e. a way of intervening in the world in order to know (Hacking 2012); furthermore, he added that a style is rooted in human innate capacities and that it is a way of *finding out* (Hacking 2009, 2012).

The Properties of the Statistical Style of Reasoning

Hacking's account of how it has been possible for our world to be dominated by probabilities contained in *The Emergence of Probability* and *The Taming of Chance* provides a perfect example of a style of reasoning that has the properties above. First of all, it was the emergence of a new form of evidence that made it possible the coming to the fore of the concept of probability. Indeed, as Hacking reminds us, in medieval thought *scientia* represented the knowledge of universal truths that is obtained by demonstration; conversely, *opinio* was associated with beliefs, resulting from argument or disputation, which could not be demonstrated. The word *probabilis* did not suggest the idea that a hypothesis was better supported by evidence than others, but meant 'worthy of approbation', i.e. approval by 'intelligent people' (Hacking 2006 [1975], 22-23). Beside approbation, there was no other concept of evidence related to opinion. What was lacking was the evidence provided by *things*, not to be confused with the evidence provided by the data of senses. To use the example given by J. L. Austin (1911-1960) and quoted by Hacking (Hacking 2006 [1975], 32), pig-like marks and buckets of food outside a sty represent the *evidence of things* for the statement that there is a pig in the sty; the coming into view of the pig represents the *evidence of the senses*. Obviously, in the Renaissance people did use the evidence of things, but for Hacking the concept was not conceptualised. For us books and testimony represent

indirect evidence reported by other people. The Renaissance had the order reversed: testimony and authority were primary, things counted as evidence only insofar as they resembled the authority of testimony and books.

The concept of sign underwent several changes – for instance, Paracelsus (1493-1541) ignored the fact that the names of stars were conventions and thought that the 'true names' of celestial bodies were signs; but later on, the distinction between conventional signs and natural ones was clearly made. The physician Girolamo Fracastoro (1483-1553) wrote that, among the 'signs in the sky, air, soil or water that are premonitory some are almost always, others are often, to be trusted. Therefore one ought not to consider them all as prognostications, but only as *signs of probability*' (Hacking 2006 [1975], 28). These changes opened the way for the evidence of signs to turn into the evidence of things. In the passage of Fracastoro, we note that, since not all signs are to be trusted with certainty, the idea of probability is connected with frequency, that is, with what happens 'almost always'. Here, we already recognize some of the properties of our statistical concept of probability. According to Hacking, in a text published in 1650 by Thomas Hobbes, the concept of evidence of things conjoined with that of frequency had already taken full shape and probability had emerged in all but name (Hacking 2006 [1975], 48). In 1662, the Port Royal logic as well, published by members of the Jansenist movement, distinguished arbitrary and conventional signs -- the concept of sign as evidence had become endemic; stable and law-like regularities became worthy of observation. Later on, the studies of the Jacques Bernoulli (1654-1705) culminated in the central limit theorem; in 1756 Thomas Simpson (1710-1761) applied the theory of errors to the discussion of uncertainty; finally, in the 1820s the first public statistics were published (Hacking 2008 [1990], 133) and some years later the statistical laws were used to explain phenomena.

Following Hacking, one could say that certain propositions acquire a truth-value only as consequence of the emergence of probability (or, better, of the evidence of things). For example, the sentence:

(S) The adult height for one sex in an ethnic group follows a normal distribution

did not have any truth-value in the Renaissance not only because the term 'normal distribution' was not defined but because the truth-value of the sentence *s* hinges on the evidence of things, not yet conceptualized before the mid-seventeenth century.[2] Moreover, to reason about this sentence means to take all the steps of a complex process – selecting a sample, measuring, classifying, dealing with errors or assessing the difference between the experimental distribution and the theoretical one. Whether or not it is meaningful for a certain community, that is, a candidate for truth or falsehood, depends on whether or not that community possesses the statistical methods and the evidence of things. Ultimately, to prove the sentence above involves, for all the means and purposes, a form of evidence not conceptualised before the seventeenth century, a new way of *thinking* but also new methods and a new way of *doing*.

This leads to another important point. The verification methods that make statistical sentences meaningful are refined versions of the procedures for testing errors and making estimations that have emerged since the eighteenth century. Hacking notes that these methods of verification are themselves couched in terms of probability:

[2] Hacking's own example is 'the gross national product of Württemberg in 1817 was 76.3 million adjusted to 1820 crowns'. For him, this sentence did not have a truth-value before 1821 'because there was no procedure of reasoning about the relevant idea' (Hacking 1992b, 143).

> the conditions of assertibility of statistical hypotheses are themselves to be determined [...] in terms of yet a new layer of sentences that themselves are statistical. (Hacking 1992b, 151)

This remark can be explained by considering once again *S* (i.e. 'The adult height for one sex in an ethnic group follows a normal distribution'). What makes *S* true or false is the existence of criteria for assessing whether the normal distribution fits the observed statistical distribution of the adult height. Typically, these criteria are measures of goodness of fit such as the chi-squared tests, which evaluate how well the observed frequencies follow a Gaussian distribution. However, the chi-squared tests are themselves statistical – for example, to 'verify' *S* one has firstly to use the differences between the theoretical and empirical frequencies for calculating a value called chi-square; then, on the basis of this value and a statistical distribution (chi-square distribution), one works out a probability. If this probability is lower than a certain number, it is considered very unlikely that *S* is true.[3] In conclusion we use a statistical distribution and other probabilistic methods to assess a statistical sentence. Hacking maintains that there is some circularity in the process:

> There is an odd way in which a style of reasoning and truth-conditions of some sentences are mutually self-authenticating. The truth is what we find out in such and such way. We recognize it as truth because of how we find it out. And how do we know that the method is good? Because it gets at the truth. (Hacking 1992b, 135)

In terms of my example, Hacking's claim is that the truth conditions of *S* are determined by a process of reasoning that includes the use of statistical procedures such as the chi-square test; on the other hand, this way of reasoning has become 'the correct standard' of assessing s because it has, to use a phrase cited of C.S. Peirce (1839-1914) by Hacking, the 'truth producing virtue' (Hacking 1992b, 135) i.e. it is able to identify whether or not a proposition is true. It is to this circularity that Hacking alludes to when he says that a way of thinking is *self-authenticating*.

To these properties of the statistical thinking, one should add that of: introducing new explanations, since statistical patterns came to be thought of as explanatory in themselves; introducing new objects, e.g. the population characterized by a mean and standard deviation; introducing new laws, e.g. the law of large numbers; and introducing new classifications, e.g. society is divided into genres of people. One can also argue that the statistical style is rooted in human innate capacities, i.e. the ability to make statistical inferences. This is a skill that has been demonstrated in both preliterate and pre-numerate individuals (Denison, Reed, and Xu 2013, Denison and Xu 2014, Xu and Garcia 2008) and it is not uniquely human (Bastos and Taylor 2020) (Johnston, Brecht, and Nieder 2023). Finally, Hacking also maintained that a style introduces new possibilities. For example, distributions of human attributes and behaviour fostered the existence of human classifications, which exercise their own causal influence on people classified but also open up new possibilities of existence. This is the point in which the style project has a continuity with Hacking's study on human kinds.

In summary, in different papers Hacking has provided a number of properties of styles of reasoning, which I list below for clarity's sake:

1) Being ways of thinking & *doing*, in particular, a way of *intervening* in the world in order to find out 'what is true' or how to change things

2) Relying on a new kind of evidence for 'finding out in the sciences'

[3] An introduction to the use of the chi-squared test can be found in (Taylor 1982 chapter 12).

3) Introducing new candidates for truth-or-falsehood, new types of explanations and/or new criteria, laws, classifications, possibilities.

4) Being self-authenticating

5) Representing a sharp break in the history of Western thought

6) Being rooted in human innate capacities

Thus, the statistical thinking, on the basis of Hacking's account in *The Emergence of Probability* and *The Taming of Chance,* possesses the properties 1) ... 6), which we may call 'the six properties of the statistical style'.

How Many Styles of Reasoning Are There?

Ian Hacking's Candidates

One might be tempted to say that a style of reasoning is any way of thinking that possesses the six properties of the statistical style. This is not convincing -- there cannot be any argument that the notion of style of reasoning should fit such a narrow criterion. Thus, we remain perplexed as to what should count as a style of reasoning in the sense of Hacking. We have even more reason to be baffled when we think that, over the last thirty years, Hacking himself, and with him many other scholars, have described several ways of thinking, stating that they count as styles of reasoning, which do not seem to satisfy all the six properties of the statistical style. For the sake of structuring the argument, it is useful to elaborate on this point.

First of all, we learn from Hacking that all the ways of thinking in Crombie's list count as styles of reasoning, but the former did not put forward any argument for showing that some of them do introduce new types of objects, evidence, laws, possibilities and new candidates for truth or falsehood, as Hacking explicitly admits (Hacking 2012, 10). This is the case of the historico-genetic style but also of the taxonomic one, which does not have criteria for the truth of sentences but for the rightness of a certain classification. Furthermore, strictly speaking, from Hacking's works it does not emerge why the postulational thinking introduces new evidence, why it is a way of doing and whether its birth is to be considered a discontinuous event in the history of thought.

In 1992 Hacking observed that two Crombie's styles, the experimental style and the style of modelling, on their own cannot account for the considerable sophistication undergone by the experimental method over the centuries. He did not deny that both experimenting and modelling can be in play in particular areas of research (Hacking 2002 [1992], 186), but he claimed that the concept that captures the genesis and development of experimental thinking is, as he called it, *the laboratory style of reasoning*. In addition to those in the Crombie's list, in 'Language Truth and Reason' (Hacking 1982) as well as in *Representing and Intervening* (Hacking 1983b), Hacking mentioned another style of thinking, that of Paracelsus, and in his 2012 paper he also explicitly referred to it as a style of reasoning (Hacking 2012, 9). Indeed, Hacking presented a sentence of Paracelsus as an example of style-dependent proposition. For him the way Paracelsus reasoned is entirely different from ours and exemplifies a 'Northern European Renaissance tradition of a bundle of hermetic interests: medicine, physiology, alchemy, herbals, astrology, divination' (Hacking 1983b, 70-71). Some might protest that this way of thinking cannot be considered scientific and cannot be included among the styles of *scientific* reasoning in the European tradition. At any rate,

Hacking has never clarified this point. In addition, in his 1992 paper 'Style for Historians and Philosophers' (Hacking 1992c), he mentioned new styles that could be added to Crombie's list. For instance, he suggested that 'the Indo-Arabic style of applied mathematics, little interested in postulation but dedicated to finding algorithms' (Hacking 2002 [1992], 185) might represent a distinct style, which he called 'algorismic' style. Later, in his lectures at the Collège de France (Hacking 2006c, 7) and in *Scientific Reason* (Hacking 2009) he brought up this idea again. Hacking regarded the algorithmic way of thinking as a *mathematical* style that, together with the postulational one, forms the 'style of mathematics': to adopt the algorithmic way of thinking means to follow methods of calculation, i.e. step-by-step list of rules that might be represented by a formula.

It has not been highlighted in literature that Hacking has also provided examples of ways of thinking that are not characterised by *durée longue* and sudden emergence. In his analysis of the history of weapon research, in *The Social Construction of What?,* Hacking wrote: 'I wish to steer away from grand talk of total conceptual schemes to more piecemeal things, and to steer away from talk of revolution to the manifold of complex ways in which [...] the form of knowledge can be determined, altered, or constrained' (Hacking 1999b, 172). He used the phrase 'form of knowledge' to mean a set of 'sentences that can be true or false, together with techniques for finding out which ones are true and which ones are false' (Hacking 1999b, 170). In providing this definition he expressly referred the reader to his 1982 and 1992 papers on styles of reasoning. Indeed, a form of knowledge possesses the properties 2) and 3) of the statistical style of reasoning, i.e. that of introducing new candidates for truth-or-falsehood and a standard of evidence to assess these sentences. As it happens in the case of the statistical style, these properties give to the forms of knowledge the role of a *historical a priori*: their emergence involves new methods, experimental norms and ways of thinking and doing that make it possible for certain sentences to become candidates for truth or falsehood. In Hacking words: '[A form of knowledge] is closely connected to Kant's idea of the origin of synthetic a priori knowledge. It is, however, very much of a *historical a priori*, to use the phrase of Michel Foucault' (Hacking 1999b, 170) The historical a priori makes a set of true-or-false sentences possible at one time, so to speak.

To be a historical a priori is, undoubtedly, the most important role of styles of reasoning, as these words of Hacking suggest: 'my study is a continuation of Kant's project of explaining why objectivity is possible [...] Kant did not think of scientific reason as a historical and collective product. We do' (Hacking 2002b, 181). With its property of being a historical a priori, a style of reasoning is a framework for achieving the explanatory goal of understanding why objectivity has been possible in different historical contexts. Ultimately, since forms of knowledge possess the property of being historical a priori (a role that Hacking assigns to styles), they deserve to be considered as candidates for being counted as styles of reasoning. Examples of forms of knowledge given by Hacking are: criteria of accuracy for missiles (Hacking 1999b, 182) or the science of early intelligence quotients (1999b, 173), but also the doctrine of trinity and 'any set of declarative sentences, together with a Ouija board and a psychic' (1999b, 170).

Other Candidates

The list of candidates for being styles of reasoning does not end here. Barry Allen argued that, from the mid-fifteenth to the mid-seventeenth centuries, theologians and inquisitors who were committed to demonology shared a way of thinking that possessed some of the properties illustrated by Hacking, for example that of being self-authenticating (Allen 1993). John Forrester proposed to include, alongside Crombie's list, another style dominant in psychoanalysis and other disciplines: reasoning in cases (Forrester 1996). Silvan Schweber and Mathias Wächter claimed that mathematical modelling and simulation on computer

constitute a new style of reasoning (Schweber and Watcher 2000). In a different research context also Arnold Davidson employed Hacking's notion of style of reasoning as a tool for examining under which conditions we can comprehend various types of statements as true or false (Davidson 2001), and argued that around 1870 a new style of thinking emerged making possible new true-or-false statements about sexual perversions. James Elwick used the label 'style of reasoning' to refer to two different sets of self-reinforcing norms in the pre-Darwinian research in biology (Elwick 2007). He noted that, in order to find out about questions concerning the development of embryos, some researchers adopted the *style of analysis/synthesis*, according to which the development proceeded through the fusion of parts, other researchers adopted the *style of palaetiology*, according to which development proceeded through a progressive specialization of the organism. Bernardette Bensaude-Vincent argued that chemistry is a style of reasoning by showing that it possesses certain properties that Hacking attributed to his notion, including the existence of techniques of self-stabilization (Bensaude-Vincent 2009). Martin Kusch noted that, following Hacking, the Christian-Catholic style should count as a style of reasoning in the sense of Hacking (Kusch 2010). Finally, Israel Belfer introduced an 'Information Laden scientific style of reasoning': according to him the impact of Information Theory on science produced a way of reasoning that satisfies Hacking's characterization (Belfer 2011). A point to be highlighted is that none of the authors of these studies has included among *their* criteria of identity all the properties of the statistical style. For example, both Allen and Kusch have not insisted on the point that a style in Hacking's sense must be a way of *doing* and a way of finding out about the world. Finally, there have been scholars who have drawn on Hacking's works to put forward a different notion of style of reasoning. For example, Bueno considered a different understanding of Hacking's concept of style: his notion of 'narrow style of reasoning' made room for the diversity of scientific practices within Hacking's styles (Bueno 2011).

The Issue of the Number of Styles of Reasoning

Faced with this rich variety of candidates for being styles of reasoning, of which some do not belong to the scientific discourse, one might wonder whether it is necessary to impose some constraints. There might be some properties that are desirable for a candidate for being a style of reasoning. For example, is self-authentication a significant property? Still less clear is whether a style is to be understood as a long-lasting way of thinking: on the one hand Hacking seems to consider endurance as an important property of styles and claims that self-authentication enables a style to be stable over time (Hacking 1996a); on the other hand, he gives examples of extinct styles.

To establish whether a way of thinking should count as a style of reasoning is crucial for assessing the entire styles project. Indeed, suppose that the reasoning of the inquisitors of the early modern period (1490-1690) mentioned above can be considered a style of reasoning; and suppose that being self-authenticating is a necessary property for being a style. Since style-dependent sentences can only be assessed by using the conceptual resources of the style they belong to, we cannot judge a demonologist as having more or less 'objective' or 'rational' claims than someone else who does not adopt that style. This is to say that, if we count the way of thinking of the demonologists as a style of reasoning, a sentence such as 'witches use gestures to cause harm' cannot be subject to independent criticism, a consequence difficult to accept. Ultimately, what counts as style of reasoning has crucial consequences for the question of whether or not the style project involves forms of epistemic relativism that we would like to avoid (cf. (Sciortino 2016, 2023d, Kusch 2010, Carter and Gordon 2014)).

Despite making *seemingly* conflicting statements concerning the issue of the number of styles, in 2012, interviewed by Andrew Lakoff, Hacking said:

> It is not surprising that one can't give a definition, a set of necessary and sufficient conditions, for being in the Crombie's list. You can't define science: a fortiori you cannot define styles of scientific reasoning. […] There are general things that one can say, but they tend to be too general. (Lakoff 2012, 227)

Hacking's last word about the number of styles was that 'it is better not to multiply six [the number of styles in Crombie's list] beyond necessity' (Hacking 2012, 6). Even so, it remains unclear why certain styles he mentioned or others that have been proposed by other scholars should be excluded. How can we justify Hacking's use of Occam's razor? I am convinced that there is no answer to this question within the project of styles of reasoning. For this reason, I turn to another area of Hacking's contributions (area *d*)).

The Category of Styles of Reasoning

Not definitions but prototypes

In *Rewriting the Soul* (1995b), Hacking scrutinized the narratives of multiple personality disorder and its links with the concept of child abuse. He pointed out that crucial knowledge about this disorder is provided by the observation that, without severe and repeated childhood trauma, multiple personality disorder is not likely to appear. However, this association between multiple personality and childhood trauma cannot be understood as causal. There are abused children who have not become multiples, and multiples who have not been subjected to child abuse. Thus, Hacking suggested that the description of multiple personality disorder in terms of early childhood trauma should not be understood as a definition but as a heuristic guide. 'Very seldom is definition the right concept in psychiatry', Hacking stated, 'The linguists' idea of a prototype is more serviceable. Child sexual abuse became part of the prototype of multiple personality. [I]f you were giving a best example of a multiple, you would include child abuse as one feature of the example' (Hacking 1995b, 83). In the first pages of *Rewriting the Soul*, Hacking had already pointed out that disorders are constituted by a set of symptoms and cannot be defined by necessary and sufficient conditions. A class of people suffering from an illness is constituted by some prototypes for that illness and by other patients whose symptoms are similar to those of the prototypes in a variety of distinct ways.

What Hacking had in mind was a theory of categorization in cognitive science called 'theory of prototypes' introduced by the psycholinguist Eleanor Rosch,[4] mentioned in *Rewriting the Soul* (Hacking 1995b, 24). We understand the world in terms of categories of things, e.g. that of 'chair', 'color' or 'game'. On the traditional account – held by philosophers from Aristotle to the latter Wittgenstein – categories are like containers, discrete sets of things which are either inside or outside the container. A thing belongs to the set if and only if it possesses some properties taken as defining that category. In contrast to this view, Rosch pointed out that a category has a 'prototype', i.e. a member with a special cognitive status -- the term initially denoted a stimulus associated to that category and crucial for its formation. Given the prototype, items that do not share all of its properties may still belong to the category. Thus, 'most, if not all, categories do not have clear-cut boundaries', says Rosch (1978, 11), and are internally graded.

Rosch's departure from the traditional Aristotelian categories rests on a series of intuitions by different scholars starting from Wittgenstein. The latter noted that we call 'game' certain activities because they have a relationship, e.g. a similarity, to other activities that we *already* call 'games'. Wittgenstein named these relationships 'family resemblances'

[4] Lakoff (1987) informs the reader of the major dissenting views about the prototype theory.

and maintained that the items falling under them form a 'family'. There is no single property shared by all the members of a family but only a number of family resemblances: mother, niece and son have blond hair but nobody else has blond hair, mother and cousin have blue eyes and cousin and aunt have thin lips and so on. Games are, in this respect, like families. Wittgenstein himself suggested that within a category there are good or bad examples of that category (Wittgenstein 1997 [1953] 70). Following these ideas, Hacking gave the example of the category of birds of which the robin can be taken as a prototype:

> Many people, asked to give an example of a bird, apparently say, "Robin." People seldom offer "ostrich" or "pelican" straight off. The robin is a best example. The robin is what the psycholinguist Eleanor Rosch calls a prototype. Ostriches differ from robins in some ways; pelicans differ from robins in others. We cannot arrange all birds in a single linear order of birdiness, saying that pelicans are more birdy than ostriches but less birdy than robins. […] The class of birds may be thought of as radial, with different birds related by different chains of family resemblances, the chains leading in to a central prototype. Likewise for mental illness, individual patients cannot be simply arranged as more "close to" or "distant from" standard cases (Hacking 1995b, 24) .

Hacking has never elaborated a view on the theory of prototypes and its possible role in the styles project. However, it is clear from his study of human kinds that for him labels work better without strict necessary and sufficient conditions. Therefore, we have every reason to apply the theory of the prototypes to the category of styles of reasoning.

Prototypes

The first question we have to address concerns the search for a prototype. I suggest that six styles of reasoning, the algorithmic, the deductive, the laboratory, the historico-genetic, the statistical and the taxonomic style, of which most of them belong to Crombie's list, correspond to what Rosch called prototypes. To count them as such, i.e. as members with a special cognitive status, rests on the intuition that, if we want to characterize both scientific thought and its history we cannot fail to mention these ways of thinking. They have endured and are still in use in scientific research; they also seem 'inescapable' because they are based on 'the four branches of logic' (Hacking 2006a, 8-9): the postulational style relies on deduction, the laboratory on induction, the historico-genetic on abduction and the taxonomic on classification.

Let us focus on the statistical style of reasoning. First of all, as I have explained in the previous sections, it has the property of being a historical a priori. Furthermore, the properties of being self-authenticating and rooted in human innate capacities confer to it the capability of enduring. Thus, it is very unlikely that one day humanity will do without the statistical style of reasoning. Additionally, property *5)* alone makes the emergence of the statistical style an event of revolutionary importance in the history of scientific thought. Finally, its practices of measuring and classifying (property *1)*) carry with them connotations of normalcy and deviation from the norm, with striking consequences on the way we conceive ourselves.

The algorithmic, the postulational, the historico-genetic and the laboratory style share, each in their own way, the properties of the statistical-style-prototype. Indeed, they too possess the six properties *1)… 6)*, as Sciortino (2023a)) has shown. Here it is important to recall the reasons why these styles are self-authenticating (property *4)*). The algorithmic style does not answer to any criteria except its own: what is found by using an algorithm is assessed by using another algorithm. The postulational style is self-authenticating because the result of a proof is always confirmed by other proofs (Hacking 2009, 40). As regards the historico-genetic style, the evidence on which scientists rely in order to infer the best

explanation may not be determined independently from the historico-genetic way of thinking itself. Finally, what makes the laboratory style self-authenticating is the fact that laboratory sciences tend to produce a sort of self-vindicating structure. Indeed, background theories, hypotheses, modelling of apparatus, data analyses and other items of knowledge are mutually adjusted to each other, as Hacking (1992a) has explained. Concerning the taxonomic style, it must be noted that, although it possesses the properties 1)...6) (Sciortino 2023a), it has a degree of family resemblance to the statistical style that is not as high as that of the other styles just mentioned. Indeed, new sentences about the hierarchical organization of living things are not true or false according to the new standards of *naturalist* historians in the Classical Age, but apt or inapt. Classifications are not true or false.

Degrees of Membership

I now move on to examine the degrees of membership of other members of the category. The chemists' way of thinking shares several resemblances with the prototypes. By *altering* materials chemists have been able to know the features of the substances, the atoms introduced by John Dalton (1766-1844) are a perfect example of the 'new objects' and the chemical formulas are 'new candidates for truth and falsehood'. What makes this way of thinking important in the history of thought is that the laboratory as a physical place was invented by the alchemists and then was adopted first by the chemists and only afterwards by other scholars. However, it is not clear whether chemistry is self-authenticating. The claim might be prone to the objection that a very large part of chemistry can be reduced to physics.

Forms of knowledge such as the science of missiles or the science of early intelligence quotients share with the prototypes the important property of being a historical a priori (property 2) and 3)) but they lack most of the other properties. On the other hand, the doctrine of trinity and the paranormal body of knowledge do not belong to the scientific discourse and, therefore, have a lower degree of resemblance to the prototype as compared to other forms of knowledge. In general, religious thinking belongs to the category of styles of reasoning in that it possesses some of the prototypical properties: it 'introduces' a variety of 'objects' (ghouls, ghosts, spirits), new truth-candidates ('God made the angels endowed with one, two, three and also four wings'), new evidence (miracles, signs, states of mind), possibilities ('it is possible for spirits to inhabit a wood'). However, believers do not systematically act and intervene 'hands-on' in the world in order to reveal patterns of relations between facts or entities that appear *prima facie* unrelated or in order to predict certain facts. This is a property of the prototypes that religions lack. Likewise, it can be said that religions do not tepresent a sharp break in the history of Western scientific thought and are not rooted in intellectual irnate capacities.

Concerning the scholastic-inquisitorial thinking, it sparked off a debate about the existence of witches (the 'new objects'), it introduced candidates for truth or falsehood ('children can be generated by incubi and succubi') and involved a new kind of evidence, e.g. confessions under torture, special signs in the body and incapacity to recite the Lord's Prayer (Allen 1993). However, its degree of resemblance to the statistical style is low for two reasons. First of all, there is no relevant sense in which the scholastic-inquisitorial thinking can be considered a way of finding out about phenomena: demonologists used methods such as torture, interrogation and physical inspection in order to assess whether a person was a minion of Satan. These methods have a very narrow range of application: they only help to find out whether or not innocent human beings are witches.

More has to be said about Allen's claim that the reasoning of demonologists is self-authenticating because of their attitude towards textual authority ('each writer cited his predecessors and became an authority worthy of citation' (Allen 1993, 112)). It seems to me that the way the scholastic-inquisitorial thinking satisfies the property of being self-authenticating does not resemble the way the prototypes satisfy it. To take as an example

the postulational style, one thing is to attribute its stability to the argumentative character of the Greek society and other historical and social circumstances, another thing is to explain its stability by noting that there is no way of assessing the demonstration of a theorem apart from that of using another demonstration. In the first case, what provides stability to the postulational style is something external to its cognitive methods: social factors. In the second case, to be self-authenticating means that the postulational style does not answer to any external canon of truth independent of itself. This very fact makes the postulational style immune to refutation and therefore stable. Ultimately, in the first case the techniques of self-authentication are external to the style, in the second case they are intrinsic to the style. I then distinguish *internal techniques of self-authentication* from *external techniques of self-authentication*. An *internal* technique refers to cases in which stability is provided by the characteristics of the way of thinking itself, which is self-reinforcing: in order to assess what has been found out by using a certain form of reasoning (e.g. abduction for the historico-genetic style, deduction for the postulational style, computation for the algorithmic style) one has to use that very form of reasoning. Prototypes are inescapable, e.g., it is not possible to say that counting is a 'wrong' method of thinking and doing: we can only assess a calculation by using another kind of calculation. On the other hand, an *external* technique refers to cases in which social, cultural and historical factors make a style stable. Religions, witchcraft, astrology and other non-scientific ways of thinking do not possess the internal self-authentication techniques that concur to giving stability to the prototypes. Astrology, for instance, is not inescapable: one can reason in a different way to show that it is not a valid form of reasoning. But one cannot reason in a different way from the algorithmic style to show that a calculation is wrong.

The Representation of the Category of Styles of Reasoning

I have drawn a diagram to represent the category of styles of reasoning (fig. 1). The diagram consists of a series of concentric circles. Each style of reasoning is represented by a point on one of the circles. Since there is no single chain of family resemblances, the styles of reasoning do not lie on a single straight line. I have placed the statistical style in the center, as it were the prototype *par excellence*, for the only reason that it has played a crucial role in the formation of the category. Indeed, one of Hacking's earliest works, *The Emergence of Probability*, outlined the physiognomy of the statistical style of reasoning, even before Hacking conceived the styles project.

I have arranged the algorithmic, the postulational, the historico-genetic, the statistical and the laboratory style on the innermost circle. Then, I have represented the taxonomic style as a point in the second circle since, as I have explained, the fact that classifications are not true or false makes it less similar to other prototypes. These six styles of reasoning are the best examples of the category. Chemistry lies on the third circle and is not a prototype, although it shares several family resemblances with the styles in the first two circles.

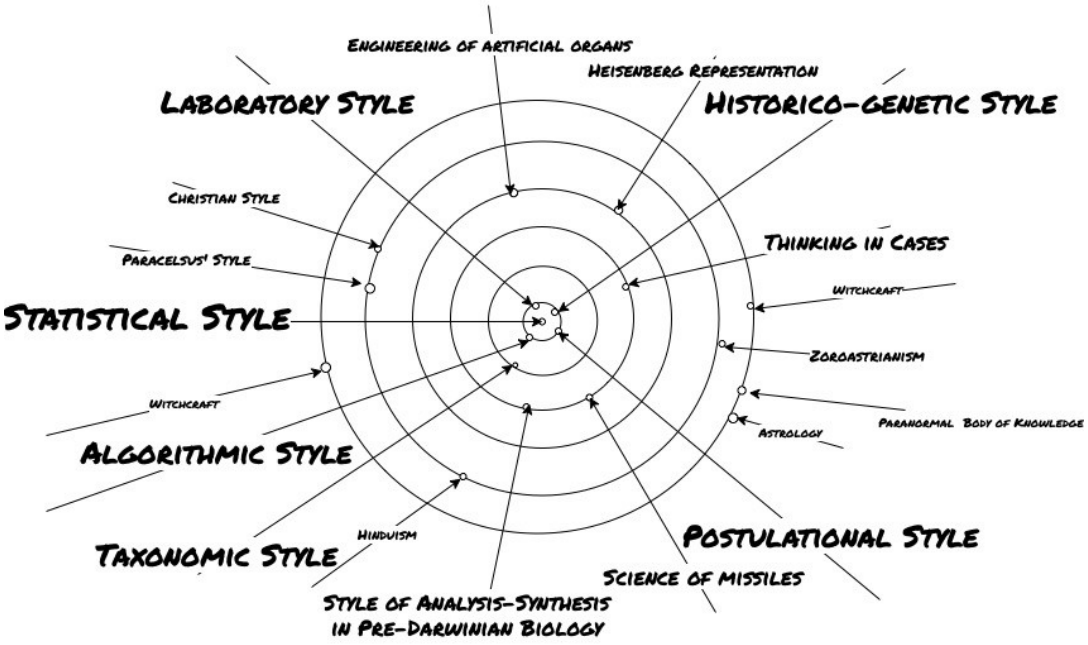

Fig. 1 A representation of the category of styles of reasoning. The statistical style is the prototype *par excellence* and lies at the center because, among other things, it has played a crucial role in the formation of the category. The further a way of thinking is from the center, the less it exemplifies the category of styles of reasoning.

Scientific forms of knowledge I have mentioned above, such as the style of analysis/synthesis in pre-Darwinian biology or the science of missiles, lie on the fourth circle: they are sufficiently close to the prototypes because they share with them the very important property of being a historical a priori, but they lack other family resemblances. Furthermore, they differ from the prototypes *in different ways*. I have arranged other members, e.g., the Heisenberg or Schrödinger representations in quantum theory, on the fifth circle. They lie far from the prototypes because they have no role as a historical a priori and they only introduce alternative methods and criteria. On the fifth circle, I have also placed other members such as the engineering of artificial organs, which represent new ways of intervening in the world but fail to resemble the prototypes in a significative way. Religions too lack crucial properties possessed by the central members: they are not ways of intervening in the world in order 'to find out the truth'; they do not rely on kinds of evidence for 'finding out in the sciences' but on kinds of evidence *tout court*; they only possess external techniques of self-vindication. Astrology, voodoo, witchcraft, paranormal bodies of knowledge and other non-scientific beliefs lie on the outer circle. The entire category expands as new styles of reasoning emerge in the history of human thought and find their representation in one of the infinite points of one of the circles.

My representation of the category of styles illustrates and clarifies what Hacking meant by the label 'style of reasoning'. All the styles he has mentioned in his writings occupy a specific point in the diagram above (Fig.1) and are characterized by a specific distance from the central prototype. In his paper '"Style" for Historians and Philosophers' (1992c), Hacking explained that he heard of Crombie lecture on 'styles of scientific thinking in the European tradition' and 'adapted the idea to metaphysics and epistemology changing the name slightly to "styles of reasoning"'. Accordingly, in his articles on styles, even the most recent ones (Hacking 2012), he has often omitted the adjective 'scientific', which qualifies the noun 'reasoning', perhaps with the intention of not limiting the discussion to scientific discourse. The fact that the diagram contains styles that belong to non-scientific discourse is therefore consistent with Hacking's terminology.

Furthermore, in his paper 'The Disunities of the Sciences' (1996b). Hacking pointed out that 'each style has its own self-stabilizing techniques', of which 'some are more effective than others' (Hacking 1996b, 73), and asked what the difference is between scientific and non-scientific reasoning. His answer was:

> Once we have a clear understanding of what, from case to case, keeps each style stable in its own way, we shall not think that there are just endless varieties of 'Rortian conversation'. Only some conversations are part of a discourse that has developed techniques of self-authentication. There does not exist a set of self-stabilizing techniques for the larger parts of morality and humanistic thought. That itself is a fact about the 'natural history of human kind'. Thus I believe that we can get a grip of the difference between moral reasoning and scientific reasoning – without invoking any 'absolute conception of reality'

In other words, for Hacking, an important feature that helps to establish whether a style can be considered as scientific is that of possessing effective techniques of self-authentication, which make it stable. My characterization of the category of styles of reasoning in terms of the prototype theory illustrates and expands Hacking's point. In the diagram (fig. 1), the styles of reasoning belonging to scientific discourse, which lie close to the center, have developed both internal and external techniques of self-authentication. The internal techniques, such as the use of probabilities to assess probabilities, are more effective than those of the styles belonging to non-scientific discourse, e.g. the style of the demonologists – as I have explained, stability is provided by the characteristics of the way of thinking itself, which is self-reinforcing. Thus, being 'scientific' and possessing effective techniques of 'self-authentication' are features that coexist. Furthermore, the effectiveness of the techniques of self-authentication decreases moving from the center towards the periphery of the diagram (fig. 1) -- the more scientific a style is, the more it is attracted towards the center of the diagram. Ultimately, although the category of 'styles of reasoning' includes non-scientific styles, its innermost core is scientific. In its essence, the notion of styles of reasoning alludes to scientific thought.

Conclusions

In this article I have addressed this issue: what is a style of reasoning? I have suggested that we can interpret this question in terms of categories – how can we understand and describe the category of styles of reasoning? I have shown that the latter can be thought of as a prototype-based category, in which some members are better examples of the category than others. Furthermore, the members of this category are related to one another without all of them having one or more properties in common that define the category. Finally, there is no clear boundary to the category of styles of reasoning. And when new ways of thinking will emerge, provided that they will resemble enough the prototype of the category of styles of reasoning, the category will expand.

I have structured my argument in four parts. The first part puts Hacking's project of styles of reasoning in the context of his research by distinguishing four areas of major scholarly contributions. The second part identifies six properties of the statistical style of reasoning by analysing two works of Hacking (*The Emergence of Probability* and *The Taming of Chance*). The third part contends that there are several other candidates for being labelled 'styles of reasoning' in the sense of Hacking so that the issue is: what is and what is not a style of reasoning? How many styles of reasoning are there? The fourth part addresses these questions from the perspective of a theory according to which categories have best examples (prototypes) but are not defined by a set of properties common to all the members

(classical view). It also argues that this approach is not at odds with Hacking's philosophical attitude and his views about categorization.

The fourth part also makes the point that six styles of reasoning are best examples of their category and focuses on the statistical style of reasoning as a prototype *par excellence*. These six styles of reasoning are: the algorithmic, the postulational, the statistical, the taxonomic, the historico-genetic and the laboratory style. Unlike the other four styles, the algorithmic and the laboratory style do not belong to Crombie's list. As to the algorithmic style, Hacking himself has suggested that this style should be added to Crombie's list by arguing that, together with the postulational one, forms the 'style of mathematics'. The laboratory style is substantially a fusion of two styles in Crombie's list, as suggested by Hacking for better capturing the development of experimental thinking. Finally, the fourth part of this paper provides a brief description of how the other members of the category of styles of reasoning are related to the central prototypes by family resemblances.

To be clearer, I have drawn what could be called the 'diagram of the category of styles of reasoning' in which different members belong to concentric circles with some farther from the statistical style (placed in the center) than others, but not in one straight line. Do ways of thinking far from the center count as 'styles of reasoning'? One may paraphrase Wittgenstein (1997 [1953] 70), when he suggested that within the category of games there are bad examples of what a game is: "Give me an example of a style of reasoning". I give the example of witchcraft and the interlocutor answers: "I didn't mean that sort of style of reasoning". In short, therefore, what is a style of reasoning in the sense of Hacking? Here is the most salient answer: the algorithmic, the postulational, the statistical, the taxonomic, the historico-genetic and the laboratory styles of reasoning are the best examples, or prototypes, of the category of styles of reasoning. There are other members of this category, but they have different degrees of membership.

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