Were experiments ever neglected? Ian Hacking and the history of philosophy of experiment[1]

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Abstract: Ian Hacking's *Representing and Intervening* is often credited as being one of the first works to focus on the role of experimentation in philosophy of science, catalyzing a movement which is sometimes called the "philosophy of experiment" or "new experimentalism". In the 1980s, a number of other movements and scholars also began focusing on the role of experimentation and instruments in science. Philosophical study of experimentation has thus seemed to be an invention of the 1980s whose central figure is Hacking. This article aims to assess this historical claim, made by Hacking himself as well as others. It does so first by highlighting how a broader perspective on the history of philosophy reveals this invention narrative to be incorrect, since experimentation was a topic of interest for earlier philosophers. Secondly, the article evaluates a revision of this historical claim also made by some philosophers of experiment: the rediscovery narrative, which frames Hacking and others as having rediscovered the work of these earlier authors. This second narratives faces problems as well. Therefore we develop a third narrative which we call the contextualist narrative. Rather than considering experimentation in an essentialist manner as a fixed research object that is either present or not in the work of specific authors, experimentation should be addressed through a narrative that asks in what way it becomes a philosophical problem for certain authors and for what purpose. Such contextualization enables a repositioning of Hacking's philosophy of experiment in relation to the specific debates in which he intervened, such as the realism-antirealism debate, the Science Wars and the debate on incommensurability.

Keywords: Ian Hacking; philosophy of experiment; experimentalism; realism; constructivism; Science Wars

1. *Introduction*

Ian Hacking's work is often credited as being one of the main inspirations

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of the "philosophy of experiment" (Hacking 1988a) or "new experimentalism" (Ackermann 1989), a philosophical program that has put the role of experiments in science on the philosophical agenda. That this movement has gained influence and status over the past 40 years is evident in the numerous books that have appeared on the topic (Gooding and Pinch 1989; Mayo 1996; Radder 2003) and the birth of related philosophical subtopics, such as exploratory experimentation (Steinle 2002; Burian 2007) or simulation (Lenhard 2007; Winsberg 2009).

Often Hacking's *Representing and Intervening* (1983) is taken as the starting point for this movement. Allan Franklin, a pioneering representative of the new experimentalists, maintained that "*Representing and Intervening* has made it legitimate to discuss the philosophy of experiment" (Franklin 1986: x). More recently, Theodore Arabatzis has stated that "it was only recently, during the 1980s, that experimental practice attracted the attention of philosophers of science" and that "Ian Hacking's work has been decisive in redressing the neglect of experiment and in bringing out its philosophical significance" (Arabatzis 2008: 162).

This historical claim can be found in Hacking's book itself. In the second part of *Representing and Intervening*, Hacking stresses that science not only represents the world but also intervenes in it. Hacking links this with the historical claim that the topic of experimentation has been ignored in the philosophy of science. "Philosophers of science constantly discuss theories and representation of reality, but say almost nothing about experiment, technology, or the use of knowledge to alter the world" (Hacking 1983: 149).

This historical claim also has been defended by other new experimentalists. For instance, in his *The Neglect of Experiment,* Franklin asks "Who was neglecting experiment? Certainly not scientists. I believed then that it was historians, philosophers, and sociologists of science [….] Actual experiments were rarely discussed" (Franklin 1986: 1). Similarly, Robert Ackermann starts his analysis by saying that "[p]revious views have left the role of scientific experimentation out of account" (Ackermann 1985: 30).

What is perhaps more noteworthy is that new experimentalists were not the first to make this historical claim about a gap in knowledge regarding experimentation. The late 1970s marked the beginning of a period characterized by what is often called a "practical" or "practice turn" (Schatzki, Knorr-Cetina and von Savigny 2001, Soler *et al.* 2014, Agazzi and Heinzmann 2015), witnessed by a sudden rise in interest in the experimental, technical, and material aspects of science.

Early influential examples of this turn in the sociology and history of science include Andrew Pickering's *Constructing Quarks* (1984), Steven Shapin's

and Simon Schaffer's *Leviathan and the Air-Pump* (1985), and Harry Collins' *Changing Order* (1985). Pickering, for instance, aimed to introduce the agency of scientists into sociological accounts: "One gets little feeling that scientists actually *do* anything in their day-to-day practice" (Pickering 1984: 8). Similarly, Shapin and Schaffer opened their book with the statement that "[o]ur subject is experiment. We want to understand the nature and status of experimental practices and their intellectual products" (Shapin and Schaffer 1985: 3).

Around the same time, sociologists began performing ethnographic studies of laboratories, again stressing the role of experimentation and intervention. The most famous example is *Laboratory Life* (1979) by Bruno Latour and Steve Woolgar, but others soon followed (Knorr-Cetina 1981; Lynch 1985; Traweek 1988). Like the new experimentalists, they stressed the innovative and revolutionary nature of their work and the goal of correcting the far-too-theoretical views dominating philosophy of science:

> What makes laboratory theories so atheoretical is the lack of any divorce from instrumental manipulation. Instead, they confront us as discursively crystallised experimental operations, and are in turn woven into the process of performing experimentation. (Knorr-Cetina 1981: 4)

Indeed, what most of these scholars and movements share is a form of self-description that stresses the *novelty* and *innovativeness* of their own approach: they advance the claim that experimentation, intervention, and instrumentation were not on the philosophical radar before they introduced it. The first section of this paper aims to evaluate this *invention narrative* and its relation to Ian Hacking.

In the second section, we show how problematic this invention narrative is from a historical point of view. We therefore go on to explore a second hypothesis: that the rise of a philosophy of experiment in the 1980s was due less to the *invention* than to the *rediscovery* of the forgotten and neglected subject of experimentation. As we will highlight, this *rediscovery narrative* also emerges, though less explicitly, in the work of the practical-turn protagonists cited in the invention narrative accounts above. To illustrate, we will focus on the example of Gaston Bachelard, exploring how his work on experimentation was taken up by more recent authors such as Hacking and Latour.

The example of Bachelard will also demonstrate, however, that the rediscovery narrative too faces problems. We therefore will argue for a third possibility, namely that it is better to abandon the idea that 'experimentation' has a fixed essence with the same significance for different periods of the history of the philosophy of science. We maintain that experimentation instead should be seen as an ambiguous, contextually informed resource that can be mobi-

lized for multiple purposes.

Thus, we end by proposing a third account that eschews taking up experimentation as a fixed research object that is either present or not and instead offers a *contextualist narrative* centered around two questions: *in what way* did experimentation become a philosophical problem for certain authors and *for what purpose*? From this perspective, we suggest that what makes Hacking's claims especially innovative is how they reconceptualize a number of existing debates – such as those on realism vs. antirealism, the Science Wars, and incommensurability – by mobilizing experimentation as a resource.

2. *The invention narrative*

As remarked in the introduction, the emphasis on the experimental aspects of science that characterized new experimentalism was in many cases accompanied by an historiographical claim about the novelty of experimentation as a philosophical subject. This *invention narrative* is widespread among philosophers, historians, and sociologists of science. In this section, we will focus on two key versions of it, advanced by Ian Hacking and Peter Galison respectively.

2.1. Hacking's back-to-bacon movement

In a paper which anticipates many of the claims of *Representing and Intervening*, Hacking argues that

> no field in the philosophy of science is more systematically neglected than experiment. Our grad school teachers may have told us that scientific method is experimental method but histories of science have become histories of theory. Experiments, the philosophers say, are of value only when they test theory. Experimental work, they imply, has no life of its own. (Hacking 1982: 71)

A few years later, in a review paper, he expands on this narrative. According to Hacking, before the 1980s "there was almost no reflective philosophy of experiment", since philosophers and historians of science had "neglected the experimental side of science" (Hacking 1988a: 147). He adds that "what little had been published was not seen as writing about experiment – that was not something to write about – but as discussion of the theory/observation distinction, or the impossibility of eliminating a theory by crucial experiment, etc." (Hacking 1988a: 147). In later publications and interviews, Hacking does not hesitate to ascribe himself the role of trailblazer with respect to philosophical studies of experimentation:

Learning from other people, I started the enthusiasm for experiment in the philosophy of science. My friend Francis Everett and I used to go walking in the Stanford hills [...] He's the person who's planning the only experimental test of the theory of gravity. It's called Gravity Probe II [...] He and I started talking about experiments. It happened that *Representing and Intervening* came out just a little bit before everybody else's books on experiments except for Bruno Latour's *Laboratory Life*. (Hacking 1992a: 5)[2]

Thus in *Representing and Intervening*, Hacking hoped "to initiate a Back-to-Bacon movement, in which we attend more seriously to experimental science" (Hacking 1983: 150). But what he actually meant was something more than a simple return to Bacon's philosophy: Hacking's aim was to reaffirm the role of scientific experiments against the exclusive attention philosophers gave the nature, structure, functions, and limits of scientific *theories*. What Hacking further argues is that new experimentalism should not only account for experiments in science but moreover should assign them a more primary role with respect to theory. The controversial claim Hacking puts forward in this respect is that "experimentation has a life of its own" (Hacking 1983: 150), largely independent of the theoretical frameworks in which it occurs. Thus, Hacking's claim to novelty lies in his point that while earlier philosophers of course had already treated the topic of experiments, they always did so in relation to (or rather, in a manner dependent on) theory. Theory-independent experimentation was never considered in philosophical discussions, according to Hacking, and it is precisely this type of experimentation that he aimed to move to the spotlight. His appeal reminds us that if we cannot conceive of experimental practices in themselves, *qua* practices, and not as the expression, extension, or confirmation of some theory, we continue to miss a fundamental trait of scientific inquiry.

2.2. Galison's critical postmodern model

Next to Hacking's, the most influential instance of a new experimentalist invention narrative is the one put forward by Peter Galison. Galison's *How experiments end* (1987) was quickly recognized as a paradigmatic study of the new experimentalism. Like Hacking, Galison makes historical claims about when experimentation became a topic of concern for philosophers and historians. He begins the preface of the book with the following claim: "Despite the slogan that science advances through experiments, virtually the entire literature of the history of science concerns theory" (Galison 1987: ix).

[2] In other places, making reference to Ravetz (1971), he seems to grant that sociologists were the real initiators of the study of experimentation: "once people did begin to think about experiment, those conducting social studies of science got there first" (Hacking 1988: 148).

Galison elaborated on this history more fully a year later by comparing three philosophical models of the nature of scientific inquiry: the positivist, anti-positivist, and 'critical postmodern' (Galison 1988). For Galison, positivists begin with a dual-layered image of science, with a shifting lower layer of theories and a steadily growing higher layer of observations, which shapes these theories and their evolution. The anti-positivists later inverted that picture, instead conceiving of observation as determined by theory and therefore arguing that, like theories, a set of observations could shift in light of a new theory.

Galison disagrees with both models and links new experimentalism with a wholly pluralistic historiographic view – which he calls the critical postmodern – characterized by a plurality of levels corresponding to globally cooperating but also partially autonomous layers. Not only does Galison disagree with the assumption of the unity of science at work in both of the previous models, he also breaks down the dichotomy between theory and observation, substituting the latter for two new layers: experiments and instruments. Experimentation is thus explicitly discussed, by Galison, in relation to the material culture of instruments and experimental materials.

3. *The rediscovery narrative*

In the previous section we outlined two examples of new experimentalist arguments claiming to offer something new in philosophy of science, namely the foregrounding of the role of experiments and instruments in science. Yet though it rarely has been questioned (for an exception, see Radder 2009), this claim can be problematized historically. Indeed, it is far from true that experiments and instruments were never a proper object of philosophical concern before the 1970s.

There are many examples of philosophical engagement with experimentation dating to the end of the 19th century or first decades of the 20th. One thinks of Ernst Mach or Ludwik Fleck in Germany, Pierre Duhem, Henri Bergson, or Gaston Bachelard in France, and John Dewey or P. W. Bridgman in the Anglo-American context. One example worth highlighting is Hugo Dingler and his book *Das Experiment: Sein Wesen und seine Geschichte*, in which we find an early example of the invention narrative, predating the above examples by fifty years: "A real 'philosophy of experiment' has never been written to my knowledge. Therefore this book should at the same time be seen as a pioneering study in this area" (Dingler 1928, i).

We will only briefly explore one such case, that of Gaston Bachelard, because Bachelard's philosophy of experiment was explicitly taken up by Hacking and others (3.1). This example underscores the invention narrative as prob-

lematic and points toward a plausible alternative hypothesis, which we call the *rediscovery narrative*. However, as we will see, this alternative hypothesis also faces problems, most notably in its inability to account for the varying ways in which Bachelard's work has been interpreted by later philosophers or has been mobilized to support very different, even opposing, claims (3.2).

3.1. The eternal return of experiments: the case of Gaston Bachelard

Bachelard's philosophy of science included a "philosophy of experiment" (Bachelard 1927: 26), which he mainly conceptualized through the concept of *phénoménotechnique*, first introduced in the early 1930s. According to Bachelard, contemporary science was characterized by a shift away from purely descriptive phenomenology toward "a phenomenotechnique through which new phenomena are not simply found but invented, constructed and built from all parts" (Bachelard 1931: 76). His philosophy thus defended a form of constructivism, in the sense it maintained that "science does not correspond to a world to be described. It corresponds to a world to be constructed" (Bachelard 1951: 46). One of the examples Bachelard provides in support of this claim is that of isotopes in mass spectroscopy:

> The trajectories that allow the separation of isotopes in the mass spectroscope do not exist in nature; one must produce them technically. They are reified theorems. We shall have to show that that which man makes by a scientific technique […] does not exist in nature and neither does a natural range of natural phenomena. (Bachelard 1949: 103)

In Bachelard's work, we thus find a clear philosophy of experiment. Although authors such as Althusser, Foucault, and Bourdieu – who mainly mobilized Bachelard's idea of an epistemological rupture (i.e. of a radical break between scientific thinking and imagination; see Simons 2018) – largely ignored this part of Bachelard's philosophy, other prominent philosophers did take it up. This is the case, for instance, of Georges Canguilhem (1955), Gilbert Simondon (see Bontems 2010), and François Dagognet (1965; 1979), who, in their respective analyses of different sciences drew from Bachelard's notion of phenomenotechnique. Their attention to Bachelard's work undermines the plausibility of a "rediscovery narrative", since Bachelard's philosophy of experiment was never forgotten.

However, it is also true that from the 1980s on there has been growing interest in Bachelard's phenomenotechnique, prevalently within Anglophone philosophy of science (Tiles 1984, Castelao-Lawless 1995, Chimisso 2001, Simons 2018). Hans Radder has even framed one of the central issues in the philosophy of experiment as the 'Bachelardian challenge': "it is the question how scien-

tific knowledge can be about a human-independent reality, if this reality is so thoroughly dependent on human work" (Radder 1993: 328). In a similar vein, Hans-Jörg Rheinberger has picked up the notion of phenomenotechnique to articulate the experimental aspects of molecular biology (Rheinberger 2005).

In new experimentalism, we also find elements of this rediscovery of Bachelard's phenomenotechnique. Galison makes occasional references to Bachelard; he describes the latter as "a gently materialist opponent of a certain stripe of neo-Kantian idealism" (Galison 1997: 18n24). Similarly, Ackermann uses Bachelard's work to explore the idea that scientific observations are discontinuous with common sense (Ackermann 1985: 88).

There is no mention of Bachelard in Hacking's *Representing and Intervening*. To some extent this is to be expected: Hacking's interest in shedding light on the power of experiments outside the limits of theory would find little of use in Bachelardian ideas of instruments or of theoretical entities as "reified theories". However, in a text whose first appearance dates to 1983, Hacking acknowledges that his position is "strikingly similar" to the one advanced by Bachelard's *Le matérialisme rationnel* (Bachelard 1953; see also Vagelli 2014: 262). There, Hacking notes, Bachelard pointed out that the introduction of new phenomena, such as the photoelectric effect, represented an "absolute discontinuity" with the history of science. However, as Hacking further argues, Bachelard also believed in scientific progress and in the accumulation of experimental techniques (Hacking 2002: 45). This latter point aligns with Hacking's idea that the phenomena produced in a scientific laboratory have the ability to persist regardless of changes in theory (Hacking 1983: 220-233). Scientific effects are relative in the sense that they are bound to our ability to recreate them; they depend on our technical skills but still cut across different theories and styles of reasoning. Phenomena that are stable, that is, that are capable of being regularly reproduced in a laboratory setting, are not objective in the absolute or foundationalist sense, because they still depend on our technical skills and on the invention of our experimental apparatuses, but they are objective in the sense that they can be largely independent of general theories.

Thus, if we consider the example of Bachelard, a *rediscovery narrative* does seems a more accurate assessment of Hacking's contribution to the philosophy of experiment than the *invention narrative*: experiments were forgotten, and new experimentalists put the topic back on the table. And indeed, we find this rediscovery narrative in several overviews of the philosophy of experiment. Friedrich Steinle for example, starts an article by discussing how Francis Bacon, John Stuart Mill, and even Pierre Duhem vividly discussed the topic of experimentation before it fell off the philosophical radar:

> Throughout the 20th century, however, philosophy of science narrowed its perspective on experiment significantly. […] Only in the 1980s, did philosophy of science again take up the question of experiment. The 'New Experimentalism' in philosophy of science arose, stimulated by Hacking's emphasis on a 'Baconian variety' of experiment, clearly emphasizing the insufficiency of the older accounts. (Steinle 2002: 408-409; cf. Feest and Steinle 2014: 274)

Nevertheless, this rediscovery narrative also faces problems. The work of earlier authors is often not addressed or analyzed in a uniform manner, leading to very divergent interpretations of earlier thinkers. We will illustrate this weakness by contrasting Hacking's interpretation of Bachelard with that of Bruno Latour. The comparison will show that it remains unclear exactly *what* is being rediscovered in the first place.

3.2. Divergent interpretations of Bachelard

The problem with the rediscovery narrative is its assumption that there is a fixed object (the 'experiment') that can be rediscovered. We want to question this assumption, again using the example of Bachelard. Although numerous authors have taken up the Bachelardian notion of phenomenotechnique, they often interpret it in radically different ways. As we saw above, Hacking, for example, advanced a relatively realist interpretation of Bachelard's philosophy (see Vagelli 2017). In the work of someone such as Bruno Latour, however, we find a quite different Bachelard.

Latour and Woolgar (1979) took inspiration from Bachelard's notion of phenomenotechnique to support the claim that facts are artificial in the sense that they are manufactured (as opposed to phony). As has been well-noted, Latour and Woolgar made this point using the example of the laboratory synthesis of TRF (Thyrotropin Releasing Factor), a paradigmatic case of the social construction of a scientific fact.

We may think TRF has been there all along, just waiting to be discovered, but Latour and Woolgar argue that it is only after 1969 and a particular series of laboratory events, exchanges, and negotiations that it became a fact. At this historical juncture, scientists decided to turn a statement about the chemical structure of TRF into an object, which then came to be seen as the cause of the statement. Yet since scientific knowledge is sustained by the network of creators and distributors of that knowledge, a change in the context of laboratory norms might turn TRF back into an artefact (or a sentence). It is in this context that Latour and Woolgar take up Bachelard's notion of phenomenotechnique:

> It is not simply that phenomena depend on certain material instrumentation; rather, the phenomena are thoroughly constituted by the material setting of the laboratory. The artificial reality, which participants describe in terms of an objective entity, has in fact been constructed by the use of inscription devices. Such a reality, which Bachelard (1953) terms the 'phenomenotechnique,' takes on the appearance of a phenomenon by virtue of its construction through material techniques. (Latour and Woolgar 1979: 64)

The contrast between this seemingly constructivist stance and Hacking's realist position is striking, and it is confirmed further if we analyze the distinction Hacking draws between scientific facts that are historically *contingent* and those that are historically *constituted*. Hacking's realism is built on the belief that phenomena are created – that is, they are "brought into being at moments of time" – but that they cannot be said to be historically constituted, because they existed before becoming objects of scientific inquiry and "are phenomena thereafter, regardless of what happens" (Hacking 2002: 44). This idea too is supported by some of Bachelard's texts, for instance when Bachelard writes:

> The electron existed before the 20th century men and women. But before them, the electron did not sing. In the triode valve, however, the electron sings. This phenomenological realization occurred at a precise point when mathematical and technical development was coming to maturity. (Bachelard 1938: 246)

With both Hacking and Latour and Woolgar supporting their claims by drawing from Bachelard's work, we end up with two competing interpretations of phenomenotechnique. One way out of this conflict would be to investigate which interpretation of Bachelard is correct and then subsequently to assess whether Hacking's philosophy of experiment was a faithful rediscovery of Bachelard's earlier work or a (perhaps fruitful) misinterpretation of it. We would like to draw a different lesson from this debate, however: namely, that it is worth questioning the assumption that there is a fixed philosophical notion called 'experiment' to be rediscovered through the work of Bachelard.

4. *The contextualist narrative*

One possible rebuttal of the previous arguments is to say that, though there have been earlier philosophers of experiment who were never forgotten, the value of Hacking's new experimentalism resides in the rediscovery of this tradition in the Anglo-American context. Although this counterclaim is partly true, it at best concludes that new experimentalism was nothing novel in the history of the philosophy of experiment but rather a mere product of the 'glo-

balized parochialism' of Anglophone philosophy and its impulse to ignore other traditions (Wolters 2015).

Another possible counterargument would be to say that a philosophy of experiment was present in Bachelard's work in only an embryonic state – and that only in the 1980s was a *proper* philosophy of experiment developed. Such an assessment finds grounds in Latour's claim that, although a step in the right direction, Bachelard's "interest in demonstrating the 'mediations' in scientific work was never extended" (Latour and Woolgar 1979: 258). However, this line of argument risks anachronism, as it assesses Bachelard's philosophical project according to the standards of a "good" philosophy of experiment as they developed from the 1980s on. Moreover, this essentialist view of what a philosophy of experiment should look like also does injustice to Hacking's originality. The value of Hacking's philosophy of experiment dwells in something other than filling in the details of Bachelard's earlier work. Indeed, we argue that it resides above all in the innovative ways Hacking mobilizes the topic of experimentation to introduce new philosophical options into well-entrenched debates. We therefore propose a *contextualist narrative* of the history of the philosophy of experiment, which we think is able to solve the problems posed by the earlier narratives while simultaneously acknowledging Hacking's unique contribution.

4.1. Resituating Hacking's work on experiments

Several scholars have noted that Hacking's famous slogan that "experimentation has a life of its own" can mean various things (Mayo 1996: 62; Soler *et al.* 2014: 7-8). Typically, it is associated with a critique of the theory-centeredness of philosophy of science: the purpose of experimentation often diverges from the mere testing of a general theory, often instead consisting in the aim of better articulating phenomena or of simply making certain that instruments work. We do not intend to contest this claim about the criticism of theory-centeredness, but by advancing a contextualist narrative we mean stress that this interpretation of Hacking leaves open the question of *why* these aspects of experimentation are philosophically relevant. It is here that context matters, since new experimentalists find it important to invoke these other non-theory-oriented dimensions of experimentation in response to specific problems found in the philosophy, history, and sociology of science.

In the framework of the sociology of scientific knowledge, authors such as David Bloor and Barry Barnes, and later Collins, Pickering, and Shapin, argued that scientific controversies are never determined by purely logical or rational means, but rather that social factors play a decisive role. In their *Leviathan and the Air-Pump*, for instance, Shapin and Schaffer argue that the production of accepted matters of fact "rested upon the acceptance of certain social and

discursive conventions, and that it depended upon the production and protection of a special form of social organization" (Shapin and Schaffer 1985: 22). In relation to experimentation, this idea was expressed most famously by Collins in his notion of 'experimenters' regress':

> The problem is that, since experimentation is a matter of skillful practice, it can never be clear whether a second experiment has been done sufficiently well to count as check on the results of a first. Some further test is needed to test the quality of the experiment – and so forth. (Collins 1985: 2)

According to Collins, whether or not an experiment is accepted as correct is, in the end, based on social consensus rather than rational argument. To make such claims, these sociologists relied on philosophical arguments about underdetermination or the empirical equivalence of different theories, taking inspiration from scholars such as W.V.O. Quine and Nelson Goodman (see Zammito 2004). It is in this sense that theory-ladenness becomes a problem: if the correctness of a theory can never be determined based on strict deductive or empirical arguments, the door remains open for sociological explanations.

It is in the context of this discussion that we can identify the value of new experimentalism as "having provided us sticks with which to beat the social constructivists" (Mayo 1996: 61). In response to the sociologists, the new experimentalists aimed to restore the constraining role of empirical evidence but in a *novel* way, moving away from traditional philosophers of science who accepted a theory-centered model of science toward the rabbit hole of underdetermination. This is indeed the type of self-positioning and framing one finds in the prefaces of Ackermann (1985), Franklin (1986), and Galison (1987). The strategy of these authors was to stress that there are no given, absolute logical and empirical constraints but that they can be *introduced* – and this is precisely what *intervening* in science is all about.

Galison, for instance, states that "there is no *strictly logical* termination point inherent in the experimental process" nor is there "a universal formula for discovery, or an after-the-fact reconstruction based on an inductive logic" (Galison 1987: 3). Nonetheless, his conclusion is not that social factors therefore determine outcomes but rather that we should look at how experimental work *introduces* new constraints: "As features of the instruments, theories, and procedures are better understood, the number of constraints on interpretation increases" (Galison 1987: 132).

Hacking follows the same path to a certain extent, stressing – especially in the works after *Representing and Intervening* – how experimentation introduces new constraints on how phenomena can be interpreted. Drawing insights from

multiple sources, including Galison's idea that not only experiments but also "instruments have a life of their own" and Pickering's extension of Duhem's thesis about auxiliary hypotheses, Hacking highlights the interplay between several levels of "plastic resources", including "theory, phenomenology of the apparatus, and the material instrumentation and objects being investigated" (1991: 237). The mutual adjustments among these levels results in both the stability (Hacking 1988b) and the "self-vindicating feature" of laboratory sciences (Hacking 1992b). When we look at Hacking's work in further detail, more specific debates come to the foreground – the realism-antirealism debate (4.2.1), the Science Wars (4.2.2), the debate on incommensurability (4.2.3) – but these nonetheless fit into the same program.

4.1.1 Experimentation as a new form of realism

Another important piece of context for Hacking's work is the realism-antirealism debate of the 1970s and 1980s, which centered around questions concerning the nature and function of scientific theories and theoretical entities: are theories objective descriptions of an independent reality or mere instrumental tools to make predictions? Do theoretical entities such as atoms really exist or are they just useful fictions? Whereas scientific realists believed that entities, states, and processes described by true theories referred to genuine entities in the world (Putnam 1971), scientific anti-realists denied this (van Fraassen 1980). For the anti-realists, scientific theories were instead instruments that at best could be useful or apt but not 'true' in the ordinary sense (van Fraassen 1980: 88).

Developed against the backdrop of this debate, Hacking's *Representing and Intervening* can be read as a reply to van Fraassen's constructive empiricism and to the corresponding claim that "science aims to give us theories which are empirically adequate; and acceptance of a theory involves a belief only that it is empirically adequate" (van Fraassen 1980: 12). Here Hacking introduces an idea that is typically linked to discussions of his philosophy of experiment: *experimental realism*. Whereas van Fraassen's anti-realist stance encompasses both theories and theoretical entities, Hacking argues, on the contrary, that in many cases we can have compelling evidence supporting our belief in the existence of electrons without necessarily having a plausible theoretical description of them. This evidence is provided by our ability to manipulate theoretical, postulated entities and use them to intervene in causal nexuses in the world. "We shall count as real what we can use to intervene in the world to affect something else, or what the world can use to affect us" (Hacking 1983: 146).

Hacking is thus anti-realist about theories but realist about theoretical

entities. He grounds this distinction in the claim that "[i]f you can spray electrons, then they are real" (Hacking 1983: 23). In other words, more than the theory describing the electron, it is the scientist's ability to "shoot them" with a polarizing electron gun (in an experiment measuring the charge of the quark) that provides the best evidence of their actual existence. His point is that "by the time we can use the electron to manipulate other parts of nature in a systematic way, the electron has ceased to be something hypothetical, something inferred" (Hacking 1983: 262). He thus mobilizes philosophy of experiment to shift the existing realism-antirealism debate, by introducing a new kind of realism whose defining traits are the active, pragmatic, and heuristic functions of experimentation.

4.1.2 The science wars

The realism vs. antirealism debate eventually gave birth to a subsequent debate in the 1990s known as the Science Wars, which opposed scientists and constructivists (Ross 1996; Gieryn 1999). One of the main points of divergence or "sticking points" dividing the two sides was whether scientific classifications are "natural", that is, found in nature or humanly created (Hacking 1999).

In this context, Hacking was able to draw on the distinction he had previously developed between natural kinds and interactive kinds (Hacking 1995). According to Hacking, the objects of the natural sciences are natural kinds and indifferent to our categorization, whereas human or social kinds are shaped by the interaction between a given scientific category and a subject thus categorized. This divide partially maps onto the Hacking distinction we already encountered in 3.2, between facts that are historically *contingent* and those that are historically *constituted*. Hacking uses the examples of the laser and the maser (Hacking 1983: 226-227; 1999: 179-180), phenomena that might not have occurred in the universe before we created them. In that sense Hacking identifies them as historically contingent. Yet this does not mean they are unreal or not objective. In fact, far from being historically or humanly constituted, lasers and masers for Hacking are natural kinds.

On the other hand, within a constructivist framework, the historical and technical context of the production of a given phenomenon represents its own condition of existence. A constructivist like Latour would argue that all theoretical entities are historically contingent and constituted, both those belonging to the natural sciences and those of the social sciences. For Hacking, here constructivists are overplaying their cards so to speak. They go too far in their claims about natural kinds, though he concedes that they do have a point concerning the constructed aspect of classifications such as autism or homosexuality. The claim about entities being historically constituted is thus

not completely wrong, but Hacking argues that this is only correct for the social sciences, whose theoretical objects, being both historically contingent and historically constituted, did not exist in any specifiable form until they become objects of scientific inquiry (Hacking 2002: 11).

Thus once again, Hacking mobilizes elements of his philosophy of experiment to dismantle existing debates and move them in new directions.

4.1.3 Experimentation as new form of continuism

A final debate that Hacking tried to shake up was the one over the incommensurability of science initiated by Thomas Kuhn and Paul Feyerabend in the 1970s (Kuhn 1962; 1967; Feyerabend 1975). This is true not only of Hacking but also of Galison. Indeed, it is possible to see the emergence of the philosophy of experiment in the 1980s as a direct response to the thesis of scientific incommensurability.

In 3.2 we mentioned that, for Hacking, stable laboratory phenomena are resistant to changes in theory and can cross through and accumulate through different theoretical frameworks. Seen in this light, experimental techniques and results are the best ways to assess scientific progress. Hacking locates new forms of continuity in the production of phenomena and experimental styles. Phenomena and instruments have a "life of their own", as they have the tendency to accumulate through theoretical changes. Hacking links this insight to his interest in the different styles of scientific reasoning, ranging from mathematical postulation to statistics, which according to Hacking are also accumulative:

> What we accumulate are *experimental techniques* and *styles of reasoning.* Anglophone philosophy of science has too much debated the question of whether theoretical *knowledge* accumulates. Maybe it does not. So what? Phenomena and reasons accumulate. (Hacking 2002: 45)

This passage presents the same theme that is also present in Galison's critical postmodern model described in 2.2: a complex and patchy vision suggesting that there is "no single way in which the patterns of continuity and discontinuity are aligned and there is no reductive hierarchy" (Galison 1988: 209). The Galison model aims to recuperate the best of both the positivist and antipositivist models, while incorporating new insights drawn from new experimentalism:

> By breaking up the experimental level into intercalated patches of continuity and discontinuity we incorporate the insight of the antipositivists: experiment and experience do not give unmediated access to universal, basic propositions. At the same time, by allowing experiment to continue across theoretical breaks, we (partially) resurrects

the positivists' contention that theories do change while leaving unbroken a chain – or at least a surviving. (Galison 1988: 209)

Thus according to Galison, there can be independent continuity in experimental knowledge despite clear theoretical breaks: "periods during which theorists break with tradition do not necessarily correspond to disruptions in the subject matter, methods, procedures, and instruments of experimental physics" (Galison 1987: 13). Countering the incommensurability thesis, Galison points out that "experimental conclusions have a stubbornness not easily cancelled by theory change" (Galison 1987: 259).

Yet, Hacking's and Galison's positions do not entirely overlap. According to Hacking, for instance, it is not only phenomena that accumulate through theoretical shifts but also statements of observation. Hacking repeats the neo-positivists' belief that observational statements are made in a pre-theoretical language which makes translation between the two different theories possible (Hacking 1983: 167-185). Furthermore, he sees both neo- and anti- or post-positivists philosophers and historians of science as sitting on the same side of the divide between theory and experimentation: their approach remain theoretical and incapable of accounting for the relative autonomy of experiments. This ancillary role assigned to experimentation with respect to theory in the so-called "standard image" of science was not subverted by anti-positivists such as Karl Popper who, as Hacking remarks, believed the experimenter should not begin work until the theoretician has finished their job (Hacking 2008: 109).

Despite these differences, Hacking and Galison seem to agree on the fact that elements of a philosophy of experiment has the potential to steer the old debate over incommensurability into new directions.

5. *Conclusion*

Our reconstruction has shown that experimentation did not appear out of the blue in philosophy of science in the 1980s. A variety of traditions reflecting on the role of experiments in science existed before and were still operational at that time. We have also demonstrated that when these earlier traditions are mentioned by more recent scholars, they are often not simply 'rediscovered'. The contextualist narrative we put forward (§4) highlights how specific versions of both the invention (§2) and the rediscovery (§3) narratives that philosophers of experiment articulate usually reveal their goals vis-à-vis larger debates: there are always specific reasons why philosophers of experiment claim to either have invented the philosophical topic of experimentation or rediscovered older philosophies of experiment.

As a consequence, we maintain that experimentation should not be considered a fixed notion that is either present or not in various philosophical, historical, and sociological discourses. Rather, in its myriad appearances the topic can be grouped in (at least) two important ways: (a) by what is meant by experimentation and (b) by what the philosopher in question wishes to achieve by invoking experimentation. Only a contextualist narrative can resolve the problems we encountered with both the invention and the rediscovery narratives while simultaneously acknowledging the specificity of Hacking's answers to both (a) and (b).

Of course, if one wishes to assess Hacking's contribution to the history of the philosophy of experiment fully, a great number of other questions remain. Once one accepts that experimentation can shift in meaning and use, new avenues for a genuine history of the philosophy of experiment are opened up. We therefore would like to end this article by briefly highlighting three different avenues for future research in the history of the philosophy of experiment.

First of all, we must take into account shifts that have occurred in *philosophy* itself, not only in terms of its professionalization but also in terms of the specific topics and issues it deems central or relevant. From this perspective, when assessing recent or earlier philosophies of experiment, it is key to understand how experiments emerged for these authors as a site of philosophical preoccupation. For instance, to assess Hacking's innovative contribution to the philosophy of experiment, we first must identify and evaluate what motivated his reflections on experimentation. This is the approach we have tried to employ in this paper, which we think could be extended to other recent philosophers of experiment.

Secondly, we must examine the '*regional' meaning of experimentation in different domains of knowledge* as well as *developments within these sciences* themselves – not only in terms of how specific scientific disciplines have developed throughout the 20th century but also in terms of which science is considered paradigmatic at specific moments in time. From this perspective, it is to be expected that reflecting on the form of mathematical physics dominant in the period immediately following Einstein's theories, as in Bachelard's case, would require a very different approach than working on the high-energy physics and biochemistry prevalent in the second half of the 20th century that Hacking and Latour respectively studied.

Finally, to fully grasp Hacking's philosophy of experiment also requires examining how the *role of experimentation itself has shifted in science and society*. From this perspective, one might wonder, for instance, whether the new philosophical interest in experimentation in the 1980s was in part a product of shifts in the institutional structure of science – part of developments that put instru-

ments and intervention in the spotlight, such as Big Science (Pestre 1997) and the commodification of science (Lyotard 1979) – in ways that would not have applied for Bachelard or Dingler.

All of these questions deserve detailed analysis. While in this paper we have limited ourselves to the first, philosophical question, our hope is that future research will help elaborate a history of the philosophy of experiment that addresses all three – and gives authors such Hacking the places in that history that they rightfully deserve.

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