

On Hans Reichenbach's inductivism

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Abstract One of the first to criticize the verifiability theory of meaning embraced by logical empiricists, Reichenbach ties the significance of scientific statements to their predictive character, which offers the condition for their testability. While identifying prediction as the task of scientific knowledge, Reichenbach assigns induction a pivotal role, and regards the theory of knowledge as a theory of prediction based on induction. Reichenbach's inductivism is grounded on the frequency notion of probability, of which he prompts a more flexible version than that of Richard von Mises. Unlike von Mises, Reichenbach attempts to account for single case probabilities, and entertains a restricted notion of randomness, more suitable for practical purposes. Moreover, Reichenbach developed a theory of induction, absent from von Mises's perspective, and argued for the justification of induction. This article outlines the main traits of Reichenbach's inductivism, with special reference to his book *Experience and prediction*.

Keywords Probability · Induction · Epistemology

1 Reichenbach's probabilism

Wesley Salmon, a prominent pupil of Hans Reichenbach, wrote of his mentor: "Just as Hume was the great empiricist of the eighteenth century, so it may be, will Reichenbach be remembered as the great empiricist of the twentieth century" (Salmon 1979, pp. 2–3). There is no doubt that this statement features a distinctive trait of Reichenbach's philosophy. Echoing Salmon's statement, one could also claim that as Hume was the great inductivist of the eighteenth century, Reichenbach was the great

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inductivist of the twentieth century. Like Hume, Reichenbach was deeply convinced that prediction is the main task of science, and that induction is the essential tool for making predictions. Unlike Hume's, though, Reichenbach's inductivism is probabilistic: he regarded the combination of induction and probability as a decisive step forward in the direction pointed by Hume.

Reichenbach's empiricism is characterized by a constant attention to scientific practice flanked by a distrust of the notion of truth. In fact Reichenbach's epistemology is rooted in the conviction that it is probability, not truth, that provides the toolbox for a reconstruction of scientific knowledge in tune with scientific practice. In his address delivered to the *Neuvième Congrès International de Philosophie* (Paris, 1937) he maintained that "the ideal of an absolute truth is a phantom, unrealizable; certainty is a privilege pertaining only to tautologies, namely those propositions which do not convey any knowledge" (Reichenbach 1937, p. 90. My translation). When dealing with matters of experience, truth can at best represent the limiting case of probability, namely "a special case in which the probability value is near to one or zero. It would be illusory to imagine that the terms 'true' or 'false' ever expressed anything else than high or low probability values" (Reichenbach 1936, p. 156).

The attitude adopted in this connection inspired Reichenbach's criticism of the position assumed by Rudolf Carnap and the "Viennese school" aimed "to show that every proposition has a verifiable meaning" (Reichenbach 1936, p. 143). While sharing Carnap's concern for the problem of meaning, Reichenbach opposed the verifiability theory, calling attention to the close ties between the significance of scientific statements and their predictive character, which is a condition for their testability. Ever since the early days of logical empiricism, Reichenbach held that "the concept of probability was fundamental to any theory of knowledge" (Reichenbach 1951, p. 47).¹ By contrast, he heralded a probabilistic theory of meaning which "substituted probability relations for equivalence relations and conceived of verification as a procedure in terms of probabilities rather than in terms of truth" and "abandoned the program of defining 'the meaning' of a sentence. Instead, it merely laid down two principles of meaning; the first stating the conditions under which a sentence has meaning; the second the conditions under which two sentences have the same meaning" (Reichenbach 1951, p. 47).

It is worth recalling how back in the Thirties Carnap's interest in probability was triggered by the need to overcome the shortcomings of the verifiability theory of meaning. Evidence of the fact that Carnap's theory of probability is rooted in the problem of cognitive significance is the fact that he was the first to suggest the idea of "degree of confirmation" towards the end of "Testability and meaning" (1936–1937). Unlike Reichenbach, though, Carnap did not distrust the notion of truth, and strived to bring the notion of confirmation as close as possible to that of truth. In the Thirties and Forties Carnap regarded confirmation as a semantic concept, by definition time-independent, expressing a relationship between the meanings of two sentences, describing a certain *hypothesis* and a given body of *evidence* supporting it. Sentences expressing degrees of confirmation are analytic and their logic, namely inductive logic, is seen as

¹ In his (1951) Reichenbach dates his opposition to the verifiability theory of meaning back to 1921.

analogous to deductive logic. The only difference between the statements of inductive logic and those of deductive logic amounts to “the fact that the first contain the concept of degree of confirmation and are based on the definition of this concept, while the latter are independent of it” (Carnap 1946, p. 591).

The theory of partial definability put forward by Carnap in “Testability and meaning” was bitterly criticized by Reichenbach. To his eyes the testability criterion of meaning was quite inadequate because it did not take into account probability, and Carnap’s reduction chains were “too primitive instruments for the construction of scientific language” (Reichenbach 1951, p. 48). Reichenbach’s review of the *Aufbau* charged Carnap with reductionism and lack of consideration for the probabilistic aspects of science: “It is a puzzle to me just how logical neo-positivism proposes to include assertions of probability in its system, and I am under the impression that this is not possible without an essential violation of its basic principles” (Reichenbach [1933] 1978, vol. I, p. 407).

For Reichenbach the distinctive feature of scientific statements lay in their predictive character: “the theory of knowledge is a theory of prediction” (Reichenbach 1937, p. 89). Statements about the future are not certain, but rather probabilistic, and the theory of knowledge requires the theory of probability, which is a “theory of propositions about the future . . . in which the two truth-values, true and false, are replaced by a continuous scale of probabilities” (Reichenbach 1936, p. 159). Such a theory rests on the frequency interpretation of probability, which is the cornerstone of Reichenbach’s entire epistemology.

Before dealing with Reichenbach’s frequency theory in some detail, it is worth mentioning that following the logical empiricist orthodoxy he set himself the task of building a “probability logic”. This called for some way of bringing together probability, which can take many values, with the two values of truth and falsehood. The problem according to Reichenbach was solved by the frequency theory, which combines in the proper way statements about single events and statements about frequencies because “the frequency interpretation derives the degree of probability from an enumeration of the truth values of individual statements” (Reichenbach 1933, 1949, p. 311). When interpreted as frequency, probability refers to sequences of statements, whereas truth refers to single sentences, but since the propositional sequence “can be conceived as an extension of the concept of statement” (Reichenbach 1933, 1949, p. 312), probability logic can be seen as a logic of propositional sequences and “appears as a generalization of the logic of statements” (Reichenbach 1933, 1949, p. 313). Reichenbach’s probability logic encountered a number of criticisms but they will not be dealt with here.² Let us instead explore the main features of Reichenbach’s frequentism.

2 Reichenbach’s frequentism

We start our overview of Reichenbach’s version of the frequency interpretation of probability by comparing it with that developed by Richard von Mises, his colleague in Berlin and Istanbul. Reichenbach was concerned about distinguishing his own position

² See Eberhardt and Glymour (in press) for a more detailed treatment of Reichenbach’s probability logic.

from that of von Mises. In a letter to Bertrand Russell written in 1949 Reichenbach wrote the following with reference to Russell's book *Human Knowledge*:

I was surprised to find myself hyphenated to von Mises . . . - as much surprised, presumably, as he. You even call my theory a development of that of von Mises. I do not think this is a correct statement. My first publication on probability [*Der Begriff der Wahrscheinlichkeit für die mathematische Darstellung der Wirklichkeit*, Leipzig, 1915], which is earlier than Mises' publications, has already a frequency interpretation and a criticism of the principle of indifference . . . Mises' merit is to have shown that the strict-limit interpretation does not lead to contradictions and, further, to have provided a means for the characterization of random sequences. . . . But my mathematical theory is more comprehensive than Mises' theory, since it is not restricted to random sequences; furthermore, Mises does not connect his theory with the logical symbolism. And Mises has never had a theory of induction or of application of his theory to physical reality (Reichenbach 1978, vol. II, p. 410).

The major differences between Reichenbach's and von Mises's versions of frequentism can be summarized by saying that Reichenbach (1) admitted of a weaker notion of randomness; (2) opted for a "practical limit" instead of "strict limit"; (3) admitted of single case probability attributions; (4) developed a theory of induction; (5) had an argument for the justification of induction. Compared to von Mises's, Reichenbach's frequentism is more flexible. The overall difference between the their viewpoints, which gave rise to the divergencies just outlined, was Reichenbach's constant interest in all sorts of practical applications. By contrast, von Mises was more concerned with the mathematical development of the frequency theory and devoted great effort to laying its foundations upon the notion of randomness. Moreover, von Mises focused on the application of the theory to fields endowed with a well developed theoretical apparatus, like the kinetic theory of gases, Brownian motion, radioactivity, Planck's theory of black-body radiation.³

Randomness is the cornerstone of the theory developed by von Mises, who reaffirms the theoretical priority of this notion over that of probability. Von Mises gave an operative definition of randomness in terms of *insensitivity to place selection*. This obtains when the limiting values of the relative frequencies in a given sequence of observations—a 'collective' in von Mises's terminology—are not affected by any of all the possible selections that can be performed on it. In addition, the limiting values of the relative frequencies in the sub-sequences obtained by place selection equal those of the original sequence. This randomness condition is also called *principle of the impossibility of a gambling system*, because it reflects the impossibility of devising a system leading to a certain win in any hypothetical game. By adopting insensitivity to all possible place selections von Mises adopts an absolute, unrestricted notion of randomness. Soon after it was put forward, such a notion raised serious objections on the part of a number of authors including Abraham Wald and Alonzo Church.⁴

³ Such applications are discussed by von Mises in the last chapter of his (1939).

⁴ For more on this and other issues addressed in this article the reader is addressed to Galavotti (2005).

In addition Reichenbach adopted a critical attitude towards von Mises's view of the matter, and embraced a weaker notion of randomness, not referred to an absolute invariance domain, but rather to a restricted domain of selections "not defined by mathematical rules, but by reference to physical (or psychological) occurrences" (Reichenbach 1949, 1971, p. 150). In his words:

Random sequences are characterized by the peculiarity that a person who does not know the attributes of the elements is unable to construct a mathematical selection by which he would, on an average, select more hits that would correspond to the frequency of the major sequence. In other words, such selections will be included in the domain of invariance. In this form, the impossibility of making a deviating selection is expressed by a psychological, not a logical, statement; it refers to acts performed by a human being. This may be called a *psychological randomness* (ibid.).

Although aware of the weakness of a definition that "instead of speaking of logical impossibilities, refers only to a limitation of the technical abilities of human observers", Reichenbach believed that "such a psychological reference is indispensable... when selections in terms of physical observations are to be incorporated in the domain of invariance" (ibid.). Reichenbach's attitude towards randomness reflected his concern for scientific practice, as testified by the following passage:

All types of probability sequences are found in nature. A mathematical theory of probability should not be restricted to the study of one specific type of sequence but should include suitable definitions of various types, chosen from the standpoint of practical use (Reichenbach 1949, 1971, p. 151).

In the same spirit, Reichenbach weakened the notion of strict limit adopted by von Mises by introducing the notion of *practical limit*. This applied to "sequences that, in dimensions accessible to human observation, converge sufficiently and remain within the interval of convergence" (Reichenbach 1949, 1971, pp. 347–348). Reichenbach justified his viewpoint by the claim that "it is with sequences having a practical limit that all actual statistics are concerned" (ibid.). His position towards the notion of limit was obviously motivated by the same concern for practical applications imprinting his concept of randomness.

Like von Mises, Reichenbach held an empirical view of probability, according to which degrees of probability can only be ascertained *a posteriori*, namely based on experience alone. Such an attitude led naturally to the frequency view of probability, for the simple reason that what can be extracted from experience are frequencies. Reichenbach called the method by which probability values are obtained *induction by enumeration*. This

is based on counting the relative frequency [of a certain attribute] in an initial section of the sequence, and consists in the inference that the relative frequency observed will persist approximately for the rest of the sequence; or, in other words, that the observed value represents, within certain limits of exactness, the value of the limit for the whole sequence (Reichenbach 1949, 1971, p. 351).

The procedure described amounts to *inductive inference*, to be stated in more precise terms by what Reichenbach called the *Rule of induction*:

if the sequence has a limit of the frequency, there must exist an n such that from there on the frequency f^i ($i > n$) will remain within the interval $f^n \pm \delta$, where δ is a quantity that we can choose as small as we like, but that, once chosen, is kept constant. Now if we posit that the frequency f^i will remain within the interval $f^n \pm \delta$, and we correct this posit for greater n by the same rule, we must finally come to the correct result (Reichenbach 1949, 1971, p. 445).

As one can gather from these definitions, for Reichenbach probability and the inductive method were inextricably intertwined: on the one hand probabilities are determined by induction by enumeration and on the other hand induction is performed in a probabilistic fashion.

3 The theory of posits and the notion of weight

Echoing the terminology dear to logical empiricists who labelled metaphysical concepts ‘meaningless’, von Mises maintained that to talk of the probability of single events “has no meaning” (von Mises 1939, p. 11). For him probability referred only to collectives. Reichenbach was convinced that single-case probability attributions were required for practical applications, and made an effort to accommodate them within the frequency theory. The pivotal notion in this connection is that of *weight*, framed in his *theory of posits*.

As suggested by the above formulation of the Rule of induction, a probability attribution was what Reichenbach called a *posit*, that is “a statement with which we deal as true, although the truth value is unknown” (Reichenbach 1949, 1971, p. 373). Whenever we assess the probability of an uncertain event, we make a wager, pretty much like the gambler who “has to make a prediction before every game, although he knows that the calculated probability has a meaning only for larger numbers; and he makes his decision by betting, or as we shall say, by *positing* the more probable event” (Reichenbach 1949, 1971, p. 314). The theory of probability, or inductive inference, which as we saw amounts to the same thing, is a theory of posits.

Posits differ depending on whether they are made in a context of *primitive* or *advanced* knowledge. Reichenbach called *appraised* the posits made in a state of advanced knowledge, whereas posits made in a state of primitive knowledge were called *anticipative*, or *blind*. Within primitive knowledge no information on probabilities is available, while advanced knowledge includes some information about probabilities. In the context of primitive knowledge the Rule of induction is used to obtain probability values. By contrast, “all the questions concerning induction in advanced knowledge . . . are answered in the calculus of probabilities” (Reichenbach 1949, 1971, p. 432). Typically, scientific hypotheses are confirmed within advanced knowledge by Bayes’s rule. In this connection Reichenbach embraced a kind of Bayesianism that qualifies as strictly objective, because it requires prior probabilities to be determined on the basis of frequencies alone.

Reichenbach took posits to represent “the bridge between the probability of the . . . sequence and the compulsion to make a decision in a single case” (Reichenbach 1949, 1971, p. 315). This leads us to Reichenbach’s proposed solution of the single-case problem left open by von Mises’s frequentism. The central notion in this connection is that of *weight*, which is taken to represent the “predictional value” of sentences referring to single events. Posits made by such sentences receive a weight from the probabilities attached to the *reference class* to which the event in question is assigned. The reference class should satisfy the criterion of *homogeneity*, namely it should be chosen in such a way as to include as many cases as possible similar to the one under consideration, excluding dissimilar ones. Homogeneity is obtained through successive partitions of the reference class by means of *statistically relevant* properties. A reference class is homogeneous when it cannot be further partitioned in this way. Reichenbach’s recommendation was to choose “the narrowest class for which we have reliable statistics” (Reichenbach 1938, p. 316). Taking an example from Reichenbach, let us say that one wants to know the probability of death of a man of forty who contracted tuberculosis. Starting with the class of tubercular men of forty, a physician would presumably be in a position to narrow the reference class by taking an X-ray, and partition the initial class by means of the condition he observes. He could proceed to more and more partitions by taking into consideration further attributes, such as smoking or the environment. All relevant information available will improve the homogeneity of the reference class, while all information that does not alter the probability is irrelevant and can be neglected.

Needless to say, identification of the reference class raises serious problems, because in principle one can never be sure that all of the properties relevant to a phenomenon under study have been taken into account. The issue is well known and discussed at length in the statistical literature. Although aware of such difficulties, Reichenbach believed that the theory of probability, being the theory of prediction of uncertain events, should lead to single case assignments, simply because it would otherwise fail to accomplish its main task. In everyday life as well as in science we are compelled to act on the basis of uncertain predictions, and the theory of probability is the tool that allows us to evaluate uncertainty. In Reichenbach’s words:

The statement about a single case is not uttered by us with any pretence of its being a true statement; it is uttered in the form of a *posit*, or as we may also say . . . in the form of a *wager*. The frequency within the corresponding class determines, for the single case, the weight of the posit or wager. . . . we stand in a similar way before every future event, whether it is a job we are expecting to get, the result of a physical experiment, the sun’s rising tomorrow, or the next world-war. All our posits concerning these events figure within our list of expectations with a predictional value, a weight, determined by their probability (Reichenbach 1938, pp. 314–315).

One of the main tasks of *Experience and Prediction* is “to develop the theory of weight, which shall turn out to be identical with the theory of probability” (Reichenbach 1938, p. 24), and weight receives great attention in the book. A fundamental role of the notion of weight is that of providing the essential ingredient of the probabilistic theory of meaning that Reichenbach’s opposed to the verifiability theory fostered by

the “Viennese school”. Reichenbach’s theory of meaning is based on two fundamental principles. First, a proposition is said to be meaningful if its weight can be determined on the basis of observation; secondly, two propositions have the same meaning if their weight is the same for every possible observation that can be made. The fundamental principle underlying such a theory maintains that “*there is as much meaning in a proposition as can be utilized for action*” (Reichenbach 1938, p. 80; italics original). The strict link established by Reichenbach between meaning and action, together with the consideration that action is guided by prediction, explains the crucial role played by the notion of weight. The importance ascribed to action gives a pragmatic flavour to Reichenbach’s epistemology. Well aware of this, Reichenbach held that the importance assigned to the notion of weight within his own perspective was an improvement over other versions of pragmatism.

All posits are characterized by a weight, but while appraised posits, which are made in the context of advanced knowledge, have a definite weight, blind posits, which are made in the context of primitive knowledge, have unknown weight and are approximate in character. However, if the sequence has a limit anticipative posits can be corrected. According to Reichenbach, this is simply a consequence of the convergence assured by the Rule of induction. The method of posits gives rise to a hierarchical system, whose basic idea is described by Reichenbach as follows:

if we know the limit of the frequency in a sequence, this value can be regarded as the weight of an individual posit concerning an unknown element of the sequence. The weight may be identified with the probability of the single case . . . In order to find the limit of the frequency we use an anticipative posit; its weight is unknown. In order to determine this weight we must make an anticipative posit on a higher linguistic level; the former anticipative posit is then transformed into an appraised posit, that is, a posit of known weight. The procedure can be extended to higher and higher levels (Reichenbach 1949, 1971, p. 465).

Reichenbach called the procedure that starts with blind posits and goes on to formulate appraised posits that become part of a complex system the method of *concatenated inductions*. As an example, in *Experience and prediction* he described the case of three urns containing white and black balls, of which it is known that the ratios of the white balls to the total number of balls is 1:4; 2:4 and 3:4, but it is unknown to which of the three urns each of these ratios belongs. After four draws are made from an urn (putting back the drawn ball after each draw) three white balls are obtained. It may then be asked what is the probability of a white ball. This question can be answered by formulating a blind posit, according to which the sought probability is 3/4. At this point, one can proceed to ask what is the probability that the probability of a white ball is 3/4, which is tantamount to asking, on the basis of the draws that have been made, what is the probability that the ratios of white balls in the chosen urn is 3:4. This question regards a probability of the second level, to be expressed by an appraised posit. Reichenbach tells us that such probability, calculated by means of the probability calculus, is 27/46, so that the next drawing has two weights: “the weight 3/4 for the drawing of a white ball, and the weight 27/46 for the value 3/4 of the first weight” (Reichenbach 1938, pp. 367–368). In this case the second level weight, being greater than 1/2, confirms the blind posit. In other cases the second level weight

could suggest correcting the initial blind posit. According to Reichenbach, this kind of methodology can be applied to more complicated cases, to be dealt with by means of complex lattices of higher order probabilities forming systems of blind and appraised posits.

The fundamental feature of the method of concatenated inductions is that of being self-correcting:

By means of the inductive rule we set up posits concerning the limit of the frequency in a sequence and thus establish probability values. The probabilities so constructed can be used as the weights of certain other posits; we are thus able to construct appraised posits by means of anticipative posits. The appraised posits can even be identical with some of the anticipative posits; in other words, we can transform an anticipative posit into an appraised posit. Since the weight thus constructed can be used for a change in the posited value of the limit, we speak here of the *method of correction* (Reichenbach 1949, 1971, p. 461).

Since the method of concatenated inductions allows one to move from experience of frequencies to predictions on probabilities, it provides the bed rock underpinning the *interplay between experience and prediction*, the fundamental constituent of scientific method. Reichenbach ascribes “the overwhelming success of scientific method” (Reichenbach 1938, p. 364) to the procedure described above, or more generally to its core notion of inductive inference. The motivation underlying Reichenbach’s wholehearted trust in the inductive method, and the reason compelling him to develop his theory of posits, is the fact that induction provides the link between experience and prediction. In Reichenbach’s words:

The connecting link, within all chains of inference leading to predictions, is always the inductive inference. This is because among all scientific inferences there is only one of an overreaching type: that is the inductive inference. All other inferences are empty, tautological; they do not add anything new to the experiences from which they start. The inductive inference does; that is why it is the elementary form of the method of scientific discovery. However, it is the only form; there are no cases of connections of phenomena assumed by science which do not fit into the inductive scheme (Reichenbach 1938, p. 365).

As argued in Sect. 2, for Reichenbach induction is strictly intertwined with probability, defined in terms of frequency. He clarifies that the frequency interpretation played a twofold role in connection with probability. On the one hand, “a frequency is used as a *substantiation* for the probability statement; it furnishes the reason why we believe in the statement” (Reichenbach 1938, p. 339; italics original), on the other hand “a frequency is used for the *verification* of the probability statement; that is to say, it is to furnish the meaning of the statement” (ibid., italics original). Taken together, these two related albeit different functions account for the fact that

the observed frequency from which we start is only the basis of the probability inference; we intend to state another frequency which concerns *future observations*. The probability inference proceeds from a known frequency to one

unknown; it is from this function that its importance is derived. The probability statement sustains a prediction, and this is why we want it (*ibid.*; italics original).

While epitomizing the nature of scientific method, the interplay between experience and prediction calls into question the justification of induction. Given the strict link established by Reichenbach between induction and probability, the problem of justifying induction mingles with that of justifying the frequency notion of probability.

4 The justification of induction

Unlike von Mises, who did not address the problem of the justification of induction, Reichenbach thought that “the theory of probability involves the problem of induction, and a solution of the problem of probability cannot be given without an answer to the question of induction” (Reichenbach 1938, p. 339). Reichenbach’s proposed solution lay in the success of the inductive method. Starting from the tenet that induction cannot be justified on logical grounds, as convincingly argued by David Hume, Reichenbach sought a justification on pragmatical grounds, through “an analysis of the situation in which we employ probability statements” (Reichenbach 1938, p. 309). Since probability statements serve the purpose of guiding decisions leading to actions, they will be justified if it can be shown that they are the best possible guide to action. The path was indicated by Hume, whose theory of inductive belief as a habit was “put forward with the intention of veiling the gap pointed out by him between experience and prediction” (Reichenbach 1938, pp. 345–346). Instead of appealing to belief, for Reichenbach one should start from the incontrovertible assertion that inductive inference “cannot be dispensed with because we need it for the purpose of action” (*ibid.*) and show that it is a procedure of which one can say that it gives the best possible guide to the future.

It turns out that the frequency interpretation is amenable to this kind of pragmatical justification because it satisfies what Reichenbach calls the “principle of the greatest number of successes”, namely it leads to act in the most successful way possible. In Reichenbach’s words:

The meaning of probability statements is to be determined in such a way that our behavior in utilizing them for action can be justified.

It is in this sense that the frequency interpretation of probability statements can be carried through even if it is the happening or not happening of a single event which is of concern to us. The preference of the more probable event is justified on the frequency interpretation by the *argument in terms of behavior most favourable on the whole*: if we decide to assume the happening of the most probable event, we shall have in the long run the greatest number of successes. Thus although the individual event remains unknown, we do best believe in the occurrence of the most probable event as determined by the frequency interpretation; in spite of possible failures, this principle will lead us to the best ratio of successes which is attainable (Reichenbach 1938, pp. 309–310; italics original).

Reichenbach's argument relies on the self-correcting character of the method of concatenated inductions and on the approximate character of the rule of induction, which makes it precisely the kind of method being sought, namely "a procedure which is to furnish us the best assumption concerning the future" (Reichenbach 1938, p. 348). Given the impossibility of *proving* that the inductive method is truth preserving, or even that it leads to probable conclusions, it can still be shown that induction is a *necessary condition* of prediction. As a method of prediction, induction is subject to scientific testing, and this bears the conclusion that *if* successful predictions are attainable at all, the application of induction will assure attainment of that goal. Furthermore, Reichenbach claimed that the rule of induction "is the only method that can be used in the test of other methods of approximation, because it is the only method *of which we know* that it represents a method of approximation" (Reichenbach 1949, 1971, p. 477; italics original).

Since Reichenbach regarded knowledge as a system of posits or wagers, the argument for the justification of induction acquires a crucial relevance for his epistemology, because it impinges upon the question whether scientific knowledge is the best wager we can make. In other words, his argument does not provide a justification only for induction, but for scientific method and knowledge in general. This is emphasized by the passage ending *Experience and prediction*:

we wager on the predictions of science and wager on the predictions of practical wisdom: we wager on the sun's rising tomorrow, we wager that food will nourish us tomorrow, we wager that our feet will carry us tomorrow. Our stake is not low; all our personal existence, our life itself, is at stake. To confess ignorance in the face of the future is the tragic duty of all scientific philosophy; but, if we are excluded from knowing true predictions, we shall be glad that at least we know the road toward our best wagers (Reichenbach 1938, p. 404).

Borrowing Herbert Feigl's terminology, Reichenbach can be said to put forward a *vindication* of induction, that is a pragmatic argument that justifies the use of induction in view of the attainment of what is taken to be its end, namely the formulation of good predictions. Feigl distinguishes between two kinds of justifying procedures, called 'vindication' and 'validation'. The validation procedure, commonly used within deductive logic, consists in appealing to more and more general standards until the fundamental principles of a theory are reached. To justify such principles, what is needed is a validation by means of pragmatic considerations, typically based on the success obtained in view of the achievement of a certain goal. Given that the task of induction is to acquire new knowledge while formulating successful predictions, Feigl proposes to regard an inductive method as vindicated if it can be shown that it allows for good predictions about the future.⁵

Reichenbach's justification of induction found favour with Wesley Salmon, who made original developments of a number of Reichenbach's ideas. According to Salmon, a great merit of Reichenbach's argument is that it does not require the presupposition that there exists an order in nature. On the contrary, it avoids precisely this kind of

⁵ See Feigl (1950) for further details.

presupposition, for if nature is uniform, there is also the possibility that other methods of inference work, but we are not able to demonstrate it, as we can for the rule of induction. In case nature is not uniform, the rule of induction will not work, but other methods will not work either, for, if some other method led us to make correct predictions habitually, this fact alone would constitute a uniformity to which we could apply induction. Where induction fails, no other method can succeed. As observed by Salmon, “it should be clear that a solution such as Reichenbach’s to the problem of justification of induction avoids the necessity of any such *assumption* as the principle of uniformity of nature. The whole force of the justification is that the use of induction is reasonable whether or not nature is uniform, whatever may be meant by the assertion ‘Nature is uniform’” (Salmon 1953, p. 48).

Being grounded on the sole criterion of convergence, Reichenbach’s justification applies equally well to a whole class of asymptotic rules. Reichenbach did not regard it as too problematic and admitted all asymptotic rules, since the probability values determined by them converge in the long run. He simply claimed the superiority of the rule of induction over other methods on account of its descriptive simplicity. This does not satisfy Salmon, who points to a gap in Reichenbach’s argument because asymptotic rules do not converge uniformly, which means that they “are not in any sense empirically equivalent” (Salmon 1963, p. 28). According to Salmon descriptive simplicity would be a sufficient criterion for justifying the choice of a particular rule from the class of asymptotic rules only if these rules were empirically equivalent, but this is not the case. In various articles published in the fifties and sixties Salmon attempted to vindicate the rule of induction by imposing requirements that, once applied to the great variety of inductive rules, make it possible to isolate the rule of induction, thereby justifying it.

The problem has been also tackled by Ian Hacking, who proved that the three conditions of consistency, symmetry and invariance taken together are necessary and sufficient to fulfill the goal.⁶ Hacking’s conditions partly match those proposed by Salmon. In particular, Hacking’s consistency condition is a stronger version of Salmon’s normalizing, or “regularity” condition, imposing that no relative frequency m/n , observed in any initial section of a sequence whatsoever, can be negative, and that for every possible n so obtained all the corresponding values of m_i must add up to one. Hacking’s invariance is a stronger version of Salmon’s “requirement of linguistic invariance”, aimed to avoid the choice of the language used to describe the available evidence having any bearing on the conclusions obtained by means of inductive rules. Lastly, the symmetry condition advanced by Hacking corresponds to exchangeability, and requires that for any given value of the relative frequency observed in a sample the posited value of the limiting frequency must be insensitive to the order in which the items of the sample were observed to occur. Salmon’s attempts to combine this requirement with his vindication of induction were unsuccessful, and at the beginning of the nineties he wrote that “for 25 years, it has seemed . . . an unsurmountable obstacle to the kind of vindication I had hoped to provide” (Salmon 1991, p. 107). Put briefly, the problem raised by symmetry (alias exchangeability) is as follows. The condition

⁶ See Hacking (1968).

can easily be accepted by subjectivists, who hold that any evaluation of probability, although making use of empirical information provided by experience, is ultimately the expression of subjective opinion. By contrast Reichenbach and Salmon, who embrace an objective interpretation according to which the evaluation of probability is entirely based on empirical data, would have interpreted symmetry as a factual assumption on the nature of the population under investigation. As we have seen, Reichenbach locates the rule of induction within primitive knowledge, where no previous inductive information is available. Thus, according to Salmon, Reichenbach would have argued that “since we have no results of previous inductions to establish these factual assumptions, we are not entitled to make them” (Salmon 1991, p. 117). This makes the symmetry condition recalcitrant to a vindication in tune with Reichenbach’s approach.

Having deemed his own previous attempts unsuccessful, at the beginning of the nineties Salmon turned to a different approach. This was meant to combine the justification of induction with Reichenbach’s distinction between “context of discovery” and “context of justification”. Such a distinction was introduced right at the beginning of *Experience and prediction*, with reference to “the well-known difference between the thinker’s way of finding his theorem and his way of presenting it before a public” (Reichenbach 1938, p. 6). The idea is that epistemology is concerned with the context of justification, or in other words with the “rational reconstruction” of knowledge, whereas the context of discovery belongs to the realm of psychology. With Salmon, it may be asked to which of these contexts the rule of induction belongs. His answer is that the decision to examine a given sequence to calculate the relative frequency of one of its attributes belongs to the context of discovery. Furthermore, “the use of the rule of induction to *arrive at* a value to posit is also part of the context of discovery; at the same time, it looks like part of the context of justification as well, for the posit is justified by virtue of the rule of induction” (Salmon 1991, pp. 117–118; *italics original*). In other words, according to Salmon the application of the distinction between context of discovery and context of justification to Reichenbach’s inductive rule reveals an interplay such that assumptions introduced as hypotheses at the discovery level are to be confirmed or rejected at the justification level. Applying the same kind of reasoning to Bayesian method—which as we saw was also embraced by Reichenbach—Salmon observes that the assumption that the sampling procedure is random can be seen as a guess that can be subjected to statistical testing. In fact “what the subjective Bayesian takes as a personal probability the objective Bayesian can regard as a guess in the context of discovery” (Salmon 1991, p. 118). The symmetry condition, which would obviously be satisfied in case of random sampling, would then represent a wager in the context of discovery, to be tested in the context of justification. The conclusion drawn by Salmon is that:

Reichenbach sought to solve Hume’s problem of the justification of induction by means of a pragmatic vindication that relies heavily on the convergence properties of his rule of induction. His attempt to rule out all other asymptotic methods by an appeal to descriptive simplicity was unavailing. We found that important progress in that direction could be made by invoking normalizing conditions (consistency) and methodological simplicity (as a basis for invariance), but that they did not do the whole job. I am proposing that, in the end, Reichenbach’s

own distinction between discovery and justification holds the key to the solution (Salmon 1991, p. 119).

The “principle of methodological simplicity” mentioned by Salmon in the above passage is borrowed from Clendinnen, and embodies a version of simplicity that applies to rules instead of statements. It requires us to “adopt the simplest system of predicting rules which are compatible with, and exemplified in, the set of known facts” (quoted from Salmon 1991, p. 114).

In spite of its originality, Salmon’s argument for the justification of induction is not fully convincing. For one thing, the distinction between context of discovery and context of justification is disputable, as testified by the ongoing debate on the topic.⁷ In addition, the arguments put forward by both Reichenbach and Salmon face a fundamental difficulty in connection with convergence, the fundamental criterion underpinning the rule of induction. The problem is that with respect to any given sequence one cannot predict how far one must go before obtaining evaluations—posits in Reichenbach’s terminology—that fulfil a desired degree of accuracy. Furthermore, “even if we have arrived at that point, we have no way of knowing that we are there” (Salmon 1991, p. 103). In spite of Reichenbach’s and Salmon’s efforts, this remains an open problem.⁸ Obviously, Salmon’s strenuous attempts to justify Reichenbach’s rule of induction were inspired by their shared conviction that the inductive method rests on the frequency theory.

5 Concluding remarks

Commenting on *Experience and prediction*, Salmon observed that

Reichenbach places great stress on what he calls the ‘overreaching character’ of probabilistic reasoning, but he tells us very little about how this is accomplished. In fact, from Reichenbach’s general characterization of his theory of probability and induction, as given in the final chapter of *Experience and Prediction*, it is by no means obvious how probabilistic reasoning can achieve his goal (Salmon 1994, p. 244).

According to Salmon, the goal aimed at, namely knowledge of nature, could be reached by combining the theses advanced by Reichenbach in *Experience and prediction* with those he put forward in his volume *The direction of time*, which appeared posthumously in 1953. There Reichenbach developed a causal theory of time revolving around the “principle of the common cause”, stating that whenever an improbable coincidence occurs one should look for a common cause. Salmon believed that the combination of this principle with Bayes’s rule offered a canon for assigning different priors to general hypotheses, on the account that hypotheses embodying common causes should have higher prior probabilities than those involving improbable coincidences. Once again, Salmon’s proposal is interesting and original, but the principle of common cause is

⁷ See for instance Schickore and Steinle (2006).

⁸ Eberhardt and Glymour (in press) contains an extensive discussion of the problem.

not free from difficulties.⁹ Therefore the approach outlined by Salmon can hardly be held to admit of wide applicability.

Reichenbach's epistemology represents a unique blend of empiricism and pragmatism, originating from an unshakable trust in empiricism combined with the deeply felt conviction that our knowledge is uncertain and relies on induction. He set himself the goal of building an epistemological perspective which, although probabilistic, rested on a basis sound enough to guarantee objectivity. Such a solid bedrock was provided by the frequency interpretation of probability. Reichenbach was altogether concerned that the rational reconstruction of science by epistemology should never lose sight of scientific practice, nor of everyday life. He identified the main task of scientific statements with prediction, and held that success is the hallmark of science. Moving from this kind of perspective, Reichenbach was able to spot some crucial weaknesses of logical empiricism, to embrace a pragmatically oriented epistemology. It is somewhat ironic that in spite of his strong concern for practice his views fail precisely on application grounds.

One may contend that the problematic aspect of Reichenbach's construction lies in its core notion, the frequency interpretation of probability. An alternative, more flexible approach is offered by the subjective theory of probability. Granted that frequencies, whenever available, are the best guide to prediction and action, a subjectivist would not regard frequencies as the only ingredient for probability evaluations. By contrast, according to the subjective approach the evaluation of probability is a complex procedure that depends on objective as well as subjective elements combined in ways that are by and large determined by the context. While sharing Reichenbach's empirical and pragmatic stand, and his confidence in the Bayesian method, the subjective viewpoint abandons the distinction between context of discovery and context of justification, in the conviction that a number of contextual elements that do not fall within the realm of the context of justification, like the degree of expertise of the evaluating subject and the way in which evidence has been collected, have an important role to play. The objective character that Reichenbach attached to science and epistemology included both a commitment to scientific realism and the quest for objectivity. As convincingly argued by Salmon, Reichenbach embraced a non-metaphysical form of realism.¹⁰ This included the tenet that there are unknown probabilities, a concept totally alien to the subjective approach according to which probability belongs to our knowledge rather than to the facts. In addition, Reichenbach requires the objectivity of probability evaluations and thought that this was guaranteed by the rule of induction, which is a purely empirical method of evaluating probability. In point of fact, objectivity is also taken seriously by subjectivists, who address the problem of devising good probability appraisers and have developed an array of methods for the validation of probability assessments. One should not forget that Bruno de Finetti, the strongest opponent of "objectivism" taken as the idea that probability depends entirely on some aspects of

⁹ In this regard see for instance [Van Fraassen \(1882\)](#). Van Fraassen's article deals with Salmon's version of the "common cause principle", but some of the objections it raises impinge upon Reichenbach's formulation as well. For Salmon's use of that principle in connection with his causal theory of explanation see [Salmon \(1998\)](#).

¹⁰ See [Salmon \(1994\)](#) and [\(1999\)](#).

reality, gave substantial contributions to the problem of objectivity of probability evaluations.¹¹ The subjective viewpoint embodies a view of epistemology and rationality that strays from Reichenbach's in a number of respects. In particular, subjectivists do not share his conviction that there are correct—generally unknown—probability values to be approached by a self-correcting procedure based on an entirely empirical method like the rule of induction. They rather commit themselves to a weaker view of rationality that regards scientific knowledge as the product of the concurrence of logical and empirical elements, as well as personal and social factors.¹² While there is no question that whenever plenty of evidence is available probability assessments tend to converge in the long run, in those situations characterized by scant information subjectivism seems to have more to offer than frequentism, but the choice between these options also depends on philosophical considerations.

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¹¹ More on this point is to be found in Galavotti (2001). For more details on the subjective way of addressing the problem of objectivity see Dawid and Galavotti (2009).

¹² The reader is addressed to Galavotti (2003) for a comparison between the notions of probability developed by Reichenbach and de Finetti.

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