Foundations of Science (2006) 11: 221–247
DOI 10.1007/s10699-004-6247-9
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SALMON AND VAN FRAASSEN ON THE EXISTENCE OF UNOBSERVABLE ENTITIES: A MATTER OF INTERPRETATION OF PROBABILITY

ABSTRACT. A careful analysis of Salmon's Theoretical Realism and van Fraassen's Constructive Empiricism shows that both share a common origin: the requirement of literal construal of theories inherited by the Standard View. However, despite this common starting point, Salmon and van Fraassen strongly disagree on the existence of unobservable entities. I argue that their different ontological commitment towards the existence of unobservables traces back to their different views on the interpretation of probability via different conceptions of induction. In fact, inferences to statements claiming the existence of unobservable entities are inferences to probabilistic statements, whence the crucial importance of the interpretation of probability.

KEY WORDS: induction, interpretation of probability, Salmon W.C., scientific realism., van Fraassen B.C

1. INTRODUCTION

According to the Standard View, theories are to be construed as axiomatic calculi in which theoretical terms are given a partial observational interpretation by means of correspondence rules. The underlying conception is a strict bifurcation of the non-logical terms of the theory into an observational and a theoretical vocabulary. Indeed, the requirement of a literal construal is at the basis of both of Salmon's Statement Empiricism and van Fraassen's Constructive Empiricism. In fact, Statement Empiricism requires every statement in the theory to be true or false, and Constructive Empiricism aims at giving a *literally true* story of what the observable phenomena are.

Despite this common starting point, as it is well known, Salmon and van Fraassen strongly disagree on the existence of unobservable entities, i.e., on Theoretical Realism. In particular,

their disagreement concerns the possibility of having empirical evidence for statements about unobservables; indeed, this is clearly a question concerning inductive logic and the justification of inductive rules. Therefore, I will consider Salmon and van Fraassen's conception of induction; the analysis will show that, in order to defend his view of induction, Salmon develops an objective Bayesian approach based on the frequentist conception of probability. On the other hand, van Fraassen, as a subjective Bayesian, conceives of induction as a make-believe theory, which is definitively consistent with his view of probability as *personal* probabilities or epistemic attitudes. The other relevant point is that, in vindicating induction, both philosophers employ both concepts of probability – as frequency and as degree of belief.

Thus, the problem of the interpretation of probability turns out to be highly relevant for the issue of realism. In fact, the objective interpretation is meant to provide knowledge about the world, since probability values are quantitative expressions of some objective characteristics of the world. On the other hand, because within the subjective interpretation probability values quantitatively represent an agent's epistemic state, one can by right wonder whether the ambition to acquire knowledge about the world is given up. Hence, the two interpretations may seem incompatible with each other, namely with respect to the cognitive meaning expressed in the probability values. I think that it is not the case and in order to clarify the objective–subjective dichotomy I will propose a semantics of probability statements. The main idea is that, since "probability" is a context-dependent operator, and since operators can be applied to formulas with different scopes, there is no incompatibility. Finally, I will show that Salmon and van Fraassen's tenets on Theoretical Realism are definitely consistent with their positions on the interpretation of probability.

2. THEORETICAL REALISM VERSUS CONSTRUCTIVE EMPIRICISM: REMOTE ORIGINS FOR A LATE DIVERGENCE

The Standard View attempted to give an explication of the concept of *scientific theory*: scientific theories have canonical formulations that meet certain conditions. More precisely, a scientific

theory TC is an axiomatized system where T refers to theoretical postulates and C refers to correspondence rules specifying the admissible application of T to the observed phenomena.[1] Let T be the conjunction of the theoretical postulates, L a first-order logic language, and C the conjunction of the correspondence rules. Then a scientific theory based on T, L, and C consists of the conjunction of T and C and TC designates the theory.

The Standard View attempted to discover the nature of scientific theories by means of the examination of their linguistic formulations. Neither Salmon nor van Fraassen believe that this aspect – i.e., the linguistic formulation – is the only relevant element at stake in order to understand the structure of scientific theories; nevertheless, the Standard View represents both Salmon's and van Fraassen's background, as I will shortly show.

In the Standard View this clear-cut distinction between the observational language L_O and the theoretical language L_T is necessary to ensure that whenever a theoretical term V_T employed in L_T bears a relation with the observable level, it can be interpreted in a straightforward manner; at the same time, L_O only needs an immediate interpretation, for it is determined by observational situations.[2] When theories are submitted to empirical tests, the more tests they pass, the higher the degree of confirmation. In particular, in the realist interpretation of theories,[3] for TC to be empirically true:

(i) Statements in T must be true, and
(ii) Laws of T must be empirically true generalizations in V_T terms about behaviours of non-observable entities.

It is worth noting that one can deny that V_T-terms refer to any unobservable entities that *really exist*; but, in this case, statements involving V_T-terms will not be true or false, for those terms would be meaningless, and *a fortiori* TC would not be empirically true or false. Hence, if we are interested in the *truth* of the theory, beside the truth of statements containing V_O-terms, we should require the truth of statements containing V_T-terms, which is exactly the main claim of Theoretical Realism.

To sum up, in the Standard View a linguistic criterion of meaning permits to distinguish between observational and theoretical

terms and allows to rule out meaningless terms from the theory. On the other hand, the dichotomy observational – theoretical language raises two of problems; the problem of empirical significance, and the problem of the empirical content of scientific statements. The first is tantamount to ask *whether* we learn anything at all about unobservables from statements formulated in the theory, while the second asks *what* we learn from these statements.

Indeed, the answer to those questions already discloses a difference between Salmon and van Fraassen's tenets concerning to the ontological commitment of a theory. Whether or not a theory has empirical content depends on the correct formulation of the L_T language. When Salmon speaks of *Statement Empiricism*, he has in mind exactly the requirement of a precise linguistic formulation as developed by the Standard View.[4] Moreover, arguing in favour of Statement Empiricism Salmon maintains that the *Statement* Empiricist stance[5] is right when it claims that statements about unobservables are logically sound, and that all the evidential support must be, at bottom, observational in character.

However, while the Standard View provided a criterion to select what statements to accept in TC and what statements to rule out, Salmon goes further and opts in favour of a particular view of induction to *justify* those statements. This view of induction legitimates inferences from statements about the observables to statements about the unobservables. If statements about atoms and molecules are construed in a straightforward manner, according to Statement Empiricism, they imply that such entities exist. However, these statements cannot be formulated in a completely observational vocabulary. This is why Salmon provides an account of evidential support. Thus, if observational evidence is available for these statements, then this view is defensible. In Salmon's opinion, this is nothing but a question concerning induction.

On the other hand, van Fraassen shares the aim of the Standard View to provide a true account of what is observable and actual. However, and indeed this constitutes the core of his critique to the syntactic approach, the empirical import of a theory cannot be isolated by means of a mere linguistic distinction in theoretical and observational vocabulary.[6] According to his definition of Scientific Realism, science aims at giving us in its theories

a *literally true* story of what the world is like and the acceptance of scientific theories involves the belief that they are true.[7] Developing his Constructive Empiricism, van Fraassen replaces the requirement of truth by the requirement of *empirical adequacy*.

Anti-realism, as he points out, can be formulated in two ways: either science is or aims to be true properly, but is not literally construed, or the language of science should be literally construed but its theories need not to be true to be good.[8] The anti-realism van Fraassen holds is exactly of the second sort. The literal construal serves to rule out the construal of the language of science as a metaphor or anything similar. Nevertheless, insisting on this aspect does not imply to adopt a realist position, for it concerns only what a theory says. Epistemic attitudes related to the content of a theory are something different, and since "acceptance is not belief", it is possible to demand a literal construal and at the same time to believe that the theory be *empirically adequate* instead of true.

In the end, both Salmon and van Fraassen adopt an empiricist stance, whose roots are in the Standard View, but, in elaborating the two main issues – the linguistic formulation and the observational–theoretical dichotomy – they undertake different paths. While Salmon looks for a solid basis that carries on from Statement Empiricism to Theoretical Realism, van Fraassen, in evaluating the consequences of accepting a scientific theory, opts for a modification of the requirement of truth in favour of empirical adequacy. I stress this aspect because at first glance their tenets seem in sharp contraposition. Surely van Fraassen does not want to accept Salmon's strong ontological commitment, but the foregoing analysis has shown that despite their divergence, they share a common origin: the requirement of a literal construal of theories as developed by the Standard View. The common origin being unveiled, we are left with the problem of explaining the disagreement.

3. THEORETICAL REALISM: THE DIVERGENCE

Salmon (1984), states that Theoretical Realism involves the acceptance of the truth of statements about the existence of unobservable entities. As just shown, Salmon's starting point is *Statement*

Empiricism, that requires a correct formulation of scientific statements in the L_T-language. Since the L_T-language also includes V_T-terms referring to unobservable entities, the correctness of the Statement Empiricist stance implies that it is possible to assign a truth-value to some statements about the existence of unobservables. Salmon's challenge is to develop Theoretical Realism in such a way that it is possible to assign cognitive meaning to those statements on the basis of observational evidence but not on the mere basis of the linguistic criterion of meaning. The question concerns the possibility of having observational evidence for statements that cannot be fully formulated in observational terms.

According to the Standard View, for a scientific theory to be empirically true or false, statements involved in L_T must be, in turn, *true or false*. So, to what statements can we properly assign a truth-value? Can statements that include V_T-terms referring to unobservable entities be true or false? Salmon answers affirmatively: all statements are liable to be empirically evaluated. Whenever statements are not formulated in observational terms, it is still possible to evaluate the empirical evidence supporting them. On the other hand, van Fraassen seems to imply that it might be the case that some theoretical statements lack sufficient content, in which case we can't assign them a truth-value.

It is worth noting that Salmon and van Fraassen are not quarrelling about concepts such as "observation", "observability", "observable", for there is a naïve sense in which they would agree; though they do not provide a precise distinction between what is observable and what is not, they would agree that while chairs and tables are observable, surely atoms and genes are not. That is, their disagreement is *not* due to different assignments of truth-values to statements by virtue of a particular concept of observable playing the role of a benchmark.

So, although they both adopt the requirement of literal construal, the ontological commitment to the existence of unobservable entities is not the same. I argue, this is due to different understandings of induction. In fact the point at issue is: can we legitimately infer statements about unobservables? Different answers to this question depend upon different understandings of

induction. How it is possible from Salmon's standpoint to support and infer statements about the unobservables, I will now explain.

The scheme of reasoning Salmon provides is quite straightforward. Theoretical Realism asserts that statements about unobservables can be true or false, depending on how strongly empirical evidence supports them. In particular, a statement affirming the *existence* of unobservable entities *is* true because it is well supported by evidence. We are here dealing with what Rudolf Carnap used to call *inductive probability*: inductive probability measures the strength of support given by evidence to a hypothesis.[9]

In this sense inferences to statements about the unobservables are inferences to probabilistic statements. Because logically sound tools to evaluate evidential support exist, experimental evidence for the existence of theoretical entities is logically sound too. For example, experimental evidence for the existence of molecules found by early twentieth-century scientists is, indeed, logically sound. This means that if statements about molecules – e.g., that 4 g of He^4 contain about 6×10^{23} mono-atomic molecules – are construed in a straightforward manner, they *literally* mean that such molecules exist. Of course, whether this view is defensible depends on whether it is possible to have observational evidence for statements that cannot be fully formulated in observational terms. That is, whether from statements established on the mere basis of observation, it is possible to infer *legitimately* statements about unobservables.

This is to ask whether an inductive logic allowing such inferences exists. Because we are dealing with induction and not with deduction, we are not dealing with certainty but at least with opinion well supported by available evidence. If we are worried by this lack of certainty, Salmon reassures us: deductive inferences are not the only admissible inferences in the scientific practice. In particular – he argues – we dispose of an objective Bayesian approach.

It is worth-noting that Salmon criticizes van Fraassen because he fails to confront directly the issue of induction.[10] According to Salmon there is a crucial sense in which the logic of science is inescapably inductive; there is some sort of non-demonstrative ampliative inference that is an integral part of the logic of

science.[11] Indeed, these sound inductive inferences allow the step from the observational level to the non-observational level and we are in a position to affirm – i.e., to infer and detach – statements about unobservable entities by virtue of inductive tools. On the contrary, according to van Fraassen there is no inductive method or inductive logic – i.e., there is no such a set of rules – that allows making ampliative inferences of this sort, that is, to borrow van Fraassen's expression, induction is just a *make-believe theory*.

For Salmon, we can have *knowledge* about the world, and we can formulate theories and explanations disclosing the causal mechanism of nature. That is to say, knowledge of the world does not stop at the empirical level, but can attain the ontic level. On the other hand, van Fraassen denies our epistemic access to the ontic level, that is to say, we should stop at what is directly observable and perceivable. As far as a theory does its work, namely it *saves phenomena*, we should *accept* it as empirically adequate, but we should give up any ambitions to achieve *knowledge*.

In the end, Salmon is not completely right in this critique, for it is exactly their different positions on induction that yield their disagreement on Theoretical Realism. Van Fraassen *does* take position on induction. Further, I argue that their different positions on induction rely on different positions concerning the interpretation of probability. Of course, I am not claiming that the "ontogeny" of their philosophies chronologically starts choosing a certain interpretation of probability and ends up with a certain tenet on Scientific Realism. I'm just suggesting that, in order to wholly understand their approaches, we should go back to their studies and results on the interpretation of the probability calculus.

4. INDUCTION FROM AN EMPIRICIST STANCE

Salmon's *The Foundation of Scientific Inference* is an attempt to provide the basis of scientific inference: science embodies induction in an indispensable fashion and inductive inferences are irreducibly ampliative and non-demonstrative.[12] However, while it seems clear why non-ampliative inferences are necessarily truth-preserving, an interesting question arises whether there are any ampliative inferences also truth-preserving.

If scientific inferences were not ampliative, Salmon argues, science would be useless for prediction, postdiction and explanation. Moreover, "Any type of logically correct ampliative inference is induction; the problem of induction is to show that some particular form of ampliative inference is justifiable."[13] Besides, because of its non-demonstrative character, inductive inferences can only establish probable (not true) conclusions from true premises.

But what is the meaning of "probable" here? "Probable" here refers to the degree of rational belief, which is not a psychological attitude, but is objectively determinable by evidence. Thus, saying that a statement is probable means that it is supported (to a certain degree) by evidence. In turn, the very concept of evidence depends upon the nature of induction, because inductive evidence is determined by the rules of inductive inference employed. The problem of induction is therefore reformulated as a problem of evidence. However, this is a reformulation, not a solution.

The solution, from Salmon's standpoint, is an objective Bayesian approach, in which induction by enumeration is the primitive inductive rule, and Bayes' theorem gives the structure of inferences by which scientific hypotheses are confirmed by observational evidence. Probabilities that enter into the schema are to be interpreted as frequencies, and priors are furnished by analogical arguments.[14] As evidence accumulates and further inductive inferences are made, results become more and more securely established. Probabilities are to be interpreted as frequencies because only through this interpretation we can keep science "empirical and objective".[15]

A quotation clarifies van Fraassen's view of induction: "The ideal we inherit from the past is a notion of confirmation or evidential support which is: (a) *objective*: it is a relation solely between theory and total body of evidence, independent of the context of evaluation; (b) *comparative*: not only whether the evidence on the whole supports one theory more than another, or supports a theory more than alternative evidence would have, is objective; (c) *unique*: the propositions to be believed on the basis of the evidence are a determinate and logically consistent set, [...], and rationality requires that, with given total evidence, one believe all and only those propositions. The idea of an inductive logic or of an organon or canons of induction is exactly the idea of

a systematic description of the relation (evidence-to-propositions to be believed when this is the total evidence) described under (c)".[16]

When van Fraassen maintains that there is no inductive method or inductive logic, he means that there is no method satisfying the afore mentioned conditions, nor even anything approaching such a method.[17] What van Fraassen firmly criticizes is inductive logic as a method or procedure of theory production, hence the problem of induction devolves into the methodological problem of induction, namely, the problem of the role played by inductive inferences in the scientific practice, with special consideration for the discovery and the confirmation of hypotheses. Since formulation and confirmation of hypotheses surely *are* activities leading to ampliative conclusions by a (pretended) rational compelling rule, we definitely are in the viewfinder of van Fraassen's critique.

In the process of theory production, however, the goal of objectivity is not met: the goal is to get at an objective relation between the theory and the total body of evidence – this relation is supposed to give grounds for belief. Thus, induction leads beyond initial judgments of evidence, and these judgments of evidence become now judgments of credence or opinion. In criticizing induction, van Fraassen is disputing (i) the claim that it is a rule, (ii) the claim that it is rational compelling, and (iii) the claim that it pretends to fulfil the ideal of the scientific method. Indeed, from his point of view, there is no scientific method at all capable of producing theories we should *believe* in; in fact, acceptance is not belief, and judgments of opinion are not judgments of evidence. Judgments of opinion describe our epistemic state, while judgments of evidence are supposed to deal with a purely objective relation between the propositions taken as evidence and the theory under analysis. The extent to which our opinions are to be influenced by the evidence depends, in turn, on the type of rationality we wish to adopt.

Notice that van Fraassen describes the inductive method as a way to change opinions: the inductive method is supposed to guarantee the step from judgments of evidence to judgments of opinion. One could suggest rephrasing the inductive method as a procedure leading to recommendations of acceptance instead of

belief; nevertheless, these alternatives still remain, namely: shall we look at this method as a method that leads to truth in the long run? Or to probable truth? Or to more probable approximate truth than any alternative that as been formulated? Or probable empirical adequacy? Or what?

It is worth noting that van Fraassen is not denying the trivial claim that we do form expectations about the future, which are reasonable and yet go beyond what is not evident to us – this is all within the bounds of rationality.[18] However, it does not follow that anything merits the name of inductive logic. And even if we try to locate the problem of induction in the context of justification, induction is not what it pretends to be. In the context of justification inductive methods are supposed to evaluate whether a theory is empirically *true* or *false*, i.e., to justify the theory. But induction cannot do that.

Inductive logic, from van Fraassen's perspective, is nothing but a make-believe theory. The conviction that there must be such a thing as inductive logic, in turn, relies on the conviction that changes in rational belief must proceed according to some *rules*, and involve getting to a more informative body of opinion.[19] Induction as make-believe theory has the only purpose to shape our personal probabilities or epistemic attitudes preserving coherence. The moral on induction is that we should not be obliged to follow such a rule, though we are allowed by a permissive concept of rationality.[20]

5. THE VINDICATION OF INDUCTION AND THE INTERPRETATION OF PROBABILITY

As it is well-known, inductive inferences cannot be established with absolute certainty, but at best they can be highly probable. Consequently, theoretical statements on the existence of unobservable entities can't be established with certainty either. So, when are we allowed in asserting them? What is the *vindication method* that permits to assert those *probabilistic* statements? I will now show that the vindication strategy depends on the *interpretation* of probability and that there is a significant difference between Salmon and van Fraassen's arguments for vindication.

Inductive inferences are essentially probabilistic. *Probability*, following Salmon, is intended as *degree of rational belief*, which has to be *objectively* determined by *evidence*. That a statement has a certain probability means that it is supported to a certain degree by evidence. In turn, the notion of *inductive evidence* is determined by the rules of induction. Thus, the problem can be reformulated as follows: does inductive logic contain rules that permit to detach conclusions about unobservable entities?

The *vindication of induction* intends to show that the adoption of such rules is justified. Differently put, vindicating induction means to provide an argument showing that induction is a good method for determining what statements describing (unobservable) reality are *true*. Salmon's argument takes over Reichenbach's pragmatic justification,[21] but in addition he gives reasons to choose just one among different *asymptotic rules*.[22] Salmon mentions three conditions providing the vindication of induction by enumeration, the simplest of all asymptotic rules: *convergence condition*, *normalizing condition* and *linguistic invariance*.[23] As a proponent of the frequency interpretation, Salmon, as well as Reichenbach before him, is interested in inferring the limit of relative frequencies; thus, arguments for vindication will prominently concern rules that permit the passage from the frequency in the sample to the limit value of the virtually infinite sequence.

To sum up, in inductive inferences, "probability" is intended as degree of belief; in order to vindicate the inductive step from observational statements to theoretical statements, Salmon provides an account of probabilistic evidential support in which probability is primarily intended as relative frequency.

On the other hand, since van Fraassen equates probability statements with assertions expressing personal probabilities, or epistemic attitudes, his vindication strategy simply consists in satisfying a certain requirement of reasonableness. As a subjective Bayesian, he identifies probabilistic expressions of opinion (remember that induction is a *make-believe* theory) with the announcement of the betting odds that a rational person is willing to accept. Thus vindication visibly consists in gaining or at least not losing, according to the Dutch Book theorems.

His argument for vindication rests on the concept of calibration and potential calibration that describe the behaviour of a

forecaster. A good forecaster should be informative – namely, probability values assigned to statement should approach 0 or 1, and well calibrated – the calibration being a measure of how reliable the forecast is. Calibration is defined as follows: in the reference class P of the predictions to which an agent X assigns the value *r*, the relative frequency of true predictions is *r*. But of course in this way the calibration is testable only *a posteriori*, whereas we wish to determine *a priori* the reasonableness of the epistemic attitudes. van Fraassen then introduces the concept of *potential calibration*, that states that a set of personal probabilities is *potentially calibrated* if, and only if, it satisfies the axioms of the probability calculus. This definition is essentially equivalent to the minimal criterion of rationality required by subjective Bayesians.

It is worth noting that van Fraassen is worried about calibration because, as a subjectivist, he prefers personal probabilities, but at the same time, as a staunch empiricist, he is not willing to lose the link with empirical reality. This is the reason why he bestows such an importance on calibration; nevertheless, calibration is reformulated in terms of *potential* calibration, which just satisfies the subjectivist requirement of coherence.

It is now clear that the strategy for the vindication of induction is strictly tied to the interpretation of probability. What is less clear is how it is possible to employ both concepts – degree of belief and the relative frequency – in the same account. Also, this vagueness is due to the fact that it is commonly agreed that the degree of belief concept and the relative frequency concept belong respectively to the subjective and to the objective interpretation, considered incompatible with each other. Thus, we wonder whether there is somewhere a fallacy in Salmon's or van Fraassen's approach. Let me going into the details of their interpretations of probability first, I will then dissolve the doubt.

6. INTERPRETING PROBABILITY FROM AN EMPIRICIST STANCE

In the *Foundations of Scientific Inference* Salmon discusses the probabilistic approach as a solution to the problem of induction. He allows for two different concepts of probability. At first,

Salmon identifies the concept of probability with the frequency, namely "the probable is that which happens more often, and the improbable is that which happens seldom."[24] But later he argues that the frequency concept of probability does not help in explicating the sense of "being probable" used in inferring conclusions of inductive arguments.

Instead, we should take into account the concept of probability as degree of rational belief. In this sense, to say that a statement is probable means that one would be rationally justified in believing it. The degree of rational belief, then, is objectively determined by the evidence, that is, it is not a psychological attitude. To determine the degree to which evidence supports probabilistic statements, we have to justify, i.e., to vindicate, a rule that permits the assertion of those statements. For this purpose Salmon indicates induction by enumeration. Hence, rational degrees of belief are based on the frequency concept.

The frequency interpretation, from Salmon's standpoint, seems to satisfy all the adequacy criteria for interpretations,[25] namely, Admissibility, Ascertainability and Applicability.[26] The second and the third are particularly important, because the strict personalistic conception requires obedience only to the first criterion. In fact, it has been shown that the satisfaction of the admissibility criterion is a necessary and sufficient condition for the avoidance of incoherent betting systems, and according to personalists of any persuasions, this is the only constraint for probability assignments.

The frequency interpretation, above all, meets the applicability requirement, and thus, borrowing Bishop Butler's well-known words, it is by right a 'guide of life', that is, it is useful for predictions. For example, knowledge of the probability associated with throws of dice should have an important bearing upon the kinds of bets we are willing to make; knowledge of the probability of radioactive decay should have a bearing upon our prediction of the amount of a given substance that will remain undecayed after a certain time, etc.

As is well known, the major problem of the frequency interpretation is to assign probability values to the single case. Salmon attempts a solution in terms of reference classes and statistical relevance; this is matter for debate, but I will not get into that

debate here. Rather, I want to stress that from his standpoint frequencies are the best tools to assign probability values, simply because they are obtained from experience. Probabilities are to be interpreted as frequencies, for it is under this interpretation that we can keep science empirical and objective. Once frequencies are found in experience, analogical arguments intervene in order to assign prior values to hypotheses. This is the way we may say that we are working in accordance with the empirical stance.

So, although the frequency interpretation is useful for the probabilistic account of evidential support, it is useless when we want to explicate the meaning of "probable" in inductive inferences, for which degrees of belief work much better. Thus, if such importance is bestowed to degrees of belief why is Salmon still considered a staunch objectivist?

On the other hand, in his 1983 article on the justification of personal probabilities van Fraassen distinguishes two uses of the concept of probability. The *first* refers to the frequency interpretation: a probabilistic statement is a statement of objective fact, descriptive of the way the world is – probability theory is intended to be about actual frequencies of occurrence. The *second* use serves to express and formulate our opinion about something and the degree to which we are ignorant about it. We could suggest the epithet "objective" for the former and "subjective" for the latter. van Fraassen emphasizes that any satisfactory view about probability must explicate both uses.

In this article he attempts to demonstrate that the observance of the probability calculus in expressions of opinion is equivalent to the satisfaction of a basic frequentist criterion of rationality, providing an answer to Keynes' question *How can the frequency interpretation justify our observance of the rules of the probability calculus as intelligible and rational?*[27] The solution consists in describing expressions of judgment as expressions of epistemic attitudes and of discussing their proper evaluation under two headings: vindication and reasonableness. The basic criterion for reasonableness is the concept of potential calibration or frequency coherence, we already came across to. In other words, van Fraassen binds the activity of judgment – expressed in the probability language – to the frequency interpretation of probability.

The sharp distinction between belief and acceptance in van Fraassen's account is well-known. This distinction also applies to probabilistic theories, namely, we should distinguish what a probabilistic theory says about the world, i.e. what we are willing to accept, from what we are willing to believe. The first part of the problem, according to van Fraassen, finds its solution in his modal frequency interpretation, while belief is modelled as personal or subjective probability.

In the modal frequency interpretation[28] a probability space is a model of repeatable experiments and probabilities are assigned to *possible* outcomes from experience;[29] then, the problem consists in connecting the probability function in a model to observed frequencies. This can be done using idealizations leading from the description of the experiment to the probability space and, in turn, by a comparison of actual experience with a conceptual model – the family of repeated ideal experiments. In this way the model bears some relation with observed reality; hence we may say that we are working in accordance with the empiricist stance.

Moreover, the modal frequency interpretation is intended to be an account that identifies chance, or links it very intimately, with *actual* relative frequencies. van Fraassen proposes such account because he wants to answer the question *How and why should belief about objective chance help us to shape our expectations of what will happen?* The problem at stake is the connection between the objective side and the subjective side of probability. The crux of the connection is *Miller's Principle*:

My subjective probability that A is the case, on the supposition that the objective chance of A equals x, equals x.

$$Pr(A|\mathrm{ch}(A) = x) = x.$$

Because this is a principle of rationality, it needs to be warranted by a coherence argument. In particular, we are looking for coherence between statements about what will happen, and statements about chance. The modal frequency interpretation *plus* the personalistic conception of probability as epistemic attitudes do this work, namely, they make rational to base our subjective expectation on our beliefs about chance.

Again, because the subjectivist and the objectivist concept of probability are mixed in the same account, we may ask, wasn't

van Fraassen supposed to be a persuaded subjectivist? Why should a staunch subjectivist need frequencies?

7. THE SEMANTICS OF PROBABILISTIC STATEMENTS

Since its first formulations in 1660 when Pascal sent his results to Fermat, probability theory has gone a long way. Since then, studies looked at two different aspects of the concept of probability. First, in connection with the degree of belief warranted by evidence; second, in connection with the tendencies displayed by some chance device, to produce stable relative frequencies.[30] Nowadays, the two aspects are referred to as the subjective and the objective interpretations of probability.

To better grasp the distinction between the subjective and objective interpretation, let's think of the probabilistic language as any other language, i.e., provided of syntax and semantics. Let's also think of Kolmogorov's axiomatization as its syntax and of the different interpretations as its semantics. Concerning meaning of "probable", let's think of it as a context-dependent operator, namely its meaning changes depending on the context in which it is used. Thus, the right question is not *What is the meaning of "probability"?* but rather *What interpretation of probability better fits a given context?* Notice, however, that I am not claiming that, by means of a principle of tolerance, we should equally accept every interpretation, but rather that we should carefully analyse the semantics of probabilistic statements, for the meaning of probability is context-dependent.

For instance, throwing a dice, the principle of indifference teaches that every side has probability 1/6 to come up, provided that the dice is not biased. But suppose I'm at the racecourse and I want to bet on a horse, certainly I won't use the principle of indifference! Instead, I'll possibly bet on the horse having better chances to win, and this is determined by the available information, for instance, health conditions of the horse and of the horseman, former winnings, etc. The meaning of probability in the first and in the second case is clearly not the same.

Consider, further, the following distinction. Logical operators can be applied to well-formed formula *de dicto* or *de re*. In modal logic the necessity operator "□" can be applied just to

one term – e.g., *the number of planet is* □ (*nine*), namely *de re*, or to the whole formula – e.g., □ (*the number of planet is nine*), namely *de dicto*. Indeed, the same significant distinction might be suggested for probability. That is to say, we should not confuse statements that describe situations which are probabilistic in character, such as in quantum physics, in biology or in meteorology, just to name few, from statements that express our opinion or degree of belief with respect to those situations. In the former case probability is applied *de re*, and in the latter it is applied *de dicto*.

The distinction I propose is not completely new however. In fact, Carnap distinguished two concepts of probability: *statistical* probability versus *inductive* probability. "Statistical probability characterizes an objective situation, e.g., a state of a physical, biological, or social system; on the other hand, inductive probability does not occur *in* scientific statements, but only in judgements *about* such statements."[31] The former concept of probability corresponds to what I called *de re* probability, and the latter to what I called *de dicto* probability.

In scientific statements such as "this atom has the probability P of decaying in time *t*", or "a population with a larger number of altruist individuals has a better chance to survive and evolve", or "smoking raises the probability of lung cancer", probability is applied *de re*, namely we are interested in the stable relative frequencies produced by some chance device. We are describing a fact of nature which is probabilistic in character and in this sense we can by right call ourselves *objectivists*.

However, the case of inductive inferences is rather different. In these statements probability is applied *de dicto*, namely probabilities express our degree of belief with respect to a particular sentence. Valid inductive inferences justify our (probabilistic) opinions concerning features displayed during experimentation and in this sense we can by right call ourselves *subjectivists*.

My suggestion is that the *de dicto-de re* distinction is of much help in solving the problem raised by the vindication of the induction. There is no paradox, there is no fallacy, there is no incompatibility. Salmon and van Fraassen are just applying different interpretations of probability to different contexts. Indeed, even Carnap maintained that there is not incompatibility between the two. Both concepts are needed for science, but they fulfil quite

different functions, and "both sides are right in their positive thesis, but wrong in their polemic remarks about the other sides."[32]

Let's now consider the following questions. What are probabilities? How are probabilities known? It is worth noting that while the latter is an epistemological question, the former is clearly a metaphysical or ontological one. However, as far as the first question is concerned, it seems a quite biased question, for by asking *what* probabilities are, it seems that their existence is presupposed. Hence, it is more reasonable to start from the question *Do probabilities exist?*, before debating on their nature. As long as we quarrel about the existence of probabilities, we are implicitly referring to probability as *chance*, that is we are already within the objectivist interpretation.[33]

But, as far as we quarrel about the existence of probabilities, we can on no account fail to confront Bruno De Finetti. De Finetti, in fact, firmly stated that *probability does not exist*.[34] According to him, the case of the probability concept is just a rare one in which the concept expressed in the ordinary language has higher value than the concept mathematicians express. In ordinary language, we currently refer to probability as a guide for prediction, and it is exactly on this intuition that the concept should be modelled. It is possible, in his opinion, to reconstruct and deduce probability theory just relying on the subjectivist interpretation.

As first order logic does not concern the reliability of opinions, but just teaches us how to draw consequences preserving truth in the same way probability theory is conceived here as a multivalued logic, which is supposed to teach how to reason in the domain of probability judgments, keeping intact the coherence of the thought with itself. What is firmly denied is the existence of probability as objective chance, namely as objective feature of the world we can know. Thus, belief in objective probability entails an ontological commitment neither De Finetti nor any other subjectivist is willing to accept.[35]

The matter at stake is of considerable importance, because the objective interpretation of probability allows to acquire knowledge about empirical phenomena. In other words, cognitive meaning is granted to probability values. In fact, remember that Salmon-the objectivist holds a realist position, while van Fraassen-the subjectivist holds an antirealist position

concerning unobservable entities. Hence, what if the subjectivists were right and probability did not exist? Would the cognitive meaning of probability values disappear? Would, therefore, our ambition to *know* unobservable entities evaporate too?

I do not think this is the case, and to understand why, consider the Carnapian *c*-function. The result of an inductive inference has the structure of the so-called *c*-function: $c(h|e) = r$, where the propositions *h* and *e* express, respectively, the hypothesis and the evidence, and *r* is a real number in the interval [0, 1], i.e., *r* is a probability value; *r* represents the degree of confirmation, or of belief, or of support of the hypothesis *h* on the basis of the evidence *e*. No doubt the concept of degree of confirmation has a strong subjective connotation, and therefore belongs to the subjective framework, however, I would raise the following question: is everything *subjective* in the *c*-function? What does precisely express the evidence *e*? The evidence *e* represents the available experimental or observational evidence, viz. what we *know* about the world and on the basis of which probability values in inductive inferences are shaped. Now, if *e* is also expressed in probabilistic terms, then it is a statistical probability, borrowing Carnap's notation, or a *de re* probability, according to the notation just sketched. In other words, the subjective probability *r* is shaped on objective probabilities in *e*.

Let's now go back to Salmon and van Fraassen. Despite the fact that in the literature Salmon and van Fraassen are situated respectively among the objectivists and the subjectivists, they hold a similar position as regards the epistemological question about *how* probability values are known. In fact, in *The Foundations of Scientific Inference*, Salmon claims:

> "There is in my opinion only one acceptable answer: *experience*. Those who agree in regarding experience as the only foundation for prior probabilities belong in the camp of the frequentists. This is why I remain an unregenerate frequentist against what seems to many theorists to be overwhelming difficulties. Any other answer regarding the status of prior probabilities is, to me, epistemologically unthinkable."[36]

This is not surprising, anyway, from Salmon's standpoint, for he is an objectivist. But witness to van Fraassen, who states the main result of his modal frequency interpretation as follows:

"The probability of event A equals the relative frequency with which it would occur, were a suitably designed experiment performed often enough under suitable conditions."[37]

van Fraassen's problem is to find out a way to tie the probability function in a probabilistic model to the observed frequencies. The starting point is, once again, observed frequencies.

So, in both cases priors come from experience and we can rightly say that we are working in accordance with the empiricist stance. My further suggestion is to leave the objectivist–subjectivist contraposition aside and not to tag Salmon as objectivist and van Fraassen as subjectivist before realizing that they give the same answer to the epistemological question.

8. CONCLUSION

Salmon and van Fraassen are two leading exponents in the recent debate on Scientific Realism. The former strongly maintains a realist position about the existence of unobservable entities, while the latter defends an antirealist position. The reasons for this disagreement are even more interesting when a common starting point is unveiled: they both inherit from the Standard View the requirement of literal construal of scientific theories. Besides, a careful analysis of their philosophical tenets points out that different ontological commitments towards the unobservables are due to different conceptions of induction *via* different conceptions of the interpretation of probability.

However, understanding the reasons of the divergence does not dissolve the quarrel, since both adopt in their accounts two concepts of probability: as degree of belief *and* as relative frequency. This issue deserves a careful investigation too. In fact, Salmon is considered a staunch proponent of the objective interpretation, and van Fraassen a supporter of the subjectivist interpretation, hence we have to understand how different concepts of probability can be used in the same account.

I proposed a semantics of the probabilistic language in which the probability operator is context-dependent, namely it can be applied *de dicto* or *de re*, depending on whether the probabilistic

statement concerns probabilistic situations or our opinion about them. Indeed, the *de dicto – de re* distinction is analogous to the Carnapian distinction between statistical probability *vs*. inductive probability, better known as probability$_1$ versus probability$_2$.

Once agreed that in inductive inferences subjective probability and not objective probability is at stake, a further point needs to be addressed. In fact, I raised the question whether or not to adopt the subjective interpretation leads to give up the ambition to acquire knowledge about the world, and in particular about unobservable entities. I argued that, from an empiricist stance, this ambition is not dropped out, to the extent that degrees of belief are determined by what we *know* about the world, which indeed is the strategy employed by Salmon and van Fraassen. Thus, to tag Salmon as objectivist and van Fraassen as subjectivist is a hurried and imprecise conclusion. Despite the distance in their conceptions of probability, a meeting point is nonetheless retraceable: to interpret probability from an empiricist stance means to shape subjective probabilities from the available knowledge. In fact, both embrace Bayesianism, for Bayesianism allows learning from experience.

However, their Bayesian approaches again diverge in the constraints on probability values. As a subjective Bayesian, van Fraassen just demands coherence (admissibility, according to Salmon terminology), i.e., obedience to the axioms of the probability calculus. On the other hand, Salmon, as an objective Bayesian, requires further constraints, namely applicability and ascertainability.

The moral of this passionate debate is that the question of the interpretation of probability is of crucial importance not only for the philosophy of probability, but also for other traditional topics in philosophy of science, notably, for scientific realism. The probabilistic turn does not merely involve the employment of sophisticated techniques in experimental analysis; in addition, it concerns the more or less tacit belief in what is possible to know, that is to say, in what we believe it is possible to know about the world *through* probabilities. In other words, to adopt one or the other interpretation involve a different ontological commitment, notably, a different ontological commitment towards the existence of unobservable entities.

ACKNOWLEDGEMENTS

The author wishes to thank Michel Ghins, Vincenzo Fano and two anonymous referees for useful comments.

NOTES

1. Suppe (1977), *Introduction*; Suppe (1989), ch. 2. Of course a complete account of the Standard View should also mention seminal works by Braithwaite, Campbell, Kaplan, Nagel, Reichenbach, just to name few. But the goal here is to pinpoint the substantial core of agreement among them, mainly based on Carnap and Hempel. Indeed, I want to stress two issues: the dualism of observational language versus theoretical language, and the linguistic formulation of theories.
2. In fact, V_O-terms, i.e., observational terms are interpreted as corresponding immediately to observable properties.
3. Suppe (1977, p. 29).
4. Salmon (1984, p. 230, ffw).
5. For sake of philology, notice that Salmon used the term "stance" in 1984, long before van Fraassen stressed on his *empirical stance*. "In claiming that such statements can be established on the basis of experimental evidence, I have been adopting a statement empiricist *stance*.", Salmon (1984, p. 230), my italics .
6. In fact, suppose we adopt the linguistic distinction observable–unobservable, then any unobservable entity would differ from the observable ones in the way it lacks observable characteristics, therefore we should be able to state in the observational vocabulary that there are unobservable entities and what they are like. But, from van Fraassen's standpoint, this is exactly what we cannot do; namely, we cannot describe unobservable situations by means of an observational vocabulary. This has two consequences: first, to give up the observational–theoretical dichotomy, and second to remain agnostic about the existence of unobservable entities. Of course, this last claim is not exempt from possible criticisms, but at the moment this is not the issue in focus.
7. van Fraassen (1980), ch. 2.
8. van Fraassen (1980, p. 10, ffw).
9. Carnap (1970a, p. 440 ffw). Here Carnap distinguishes two concepts of probability: inductive probability versus statistical probability. Elsewhere he employs the better known notation 'probability$_1$' and 'probability$_2$'. (Carnap 1970b, 1971).
10. Salmon (1984, p. 231).
11. Indeed, his conception of induction is precisely what allows the step from Statement Empiricism to Theoretical Realism.

12. In ampliative inferences the content of the conclusion is not present implicitly nor explicitly in the premises. In non-demonstrative inferences the premises do not necessitate the conclusion, i.e., the conclusion could be false even if the premises are true. On the contrary, in demonstrative inferences the conclusion cannot be false if the premises are true because the conclusion says nothing more than what is already stated in the premises. In the same sense demonstrative inferences are also truth preserving.
13. Salmon (1967, p. 20).
14. An argument by analogy takes from premises about observables to conclusions about unobservables. According to Salmon, the legitimacy of this kind of argument implies the compatibility between Theoretical Realism and Statement Empiricism.
15. Salmon (1967, p. 131).
16. van Fraassen (1985, p.277), italics added.
17. Ibidem.
18. Nor we are not left with the sceptical despair of "nothing goes". In a later article van Fraassen (2000) elaborates further his view: despite traditional epistemology embodies false hopes, all successes in science were indeed produced by induction or abduction, which are, however, essentially understood as logic and mathematics.
19. Indeed, it is on this ideal of induction and on the precept of rules following that van Fraassen (1989) bases his critique of inference to the best explanation.
20. A permissive concept of rationality is analogous to the English concept of law: everything is permitted that is not explicitly forbidden; in contrast, the Prussian concept of law, states that everything is forbidden which is not explicitly allowed. So, the permissive concept of rationality requires that what is rational to believe includes anything that one is not rationally compelled to disbelieve. (van Fraassen 1989, pp. 171–172)
21. Reichenbach argued that in presence of two arguments providing general knowledge, we should prefer the one that yields knowledge of uniformities. Salmon (1968, 35) maintains that despite this pragmatic justification guarantees indistinctively all asymptotic rules, Reichenbach's argument provides powerful reasons for rejecting non-asymptotic rules. The asymptotic property, indeed, is often called to support statistical methods.
22. In asymptotic rules the difference between the observed frequency and the inferred value of the limit converges to zero for increasing sample size. Asymptotic rules follow the following scheme:

$$\text{Given } F^{n}(A, B) = m/n,$$
$$\text{to infer } \lim_{n\to\infty} F^{n}(A, B) = m/n + c,$$

Where n denotes the sample size; $n \to \infty$ denotes the increasing of the sample; c is a corrective term that produces a difference between the observed frequency and the inferred value of the limit. Induction by enumeration is the rule resulting when c is zero.

23. The *first* states that, for any member of this class, if the sequence has a limit, the inferred values given by this rule becomes and remain accurate within any desired degree of approximation. Asymptotic rules, and induction by enumeration among them, all satisfy the convergence condition. The *second* asserts that the limit of the inferred frequency cannot be negative and that the sum of the limits for a set of mutually exclusive and exhaustive attributes must be one. The *third* entails that inferences concerning the limit of the relative frequency should not be a function of the language used.
24. Salmon (1967, p. 48).
25. Salmon (1967), ch. IV.2.
26. The *Admissibility criterion* states that the interpretation of a formal system is admissible if the meaning assigned to the primitive terms in this interpretation transforms the formal axioms, and consequently all the theorems, into true statements. The *Ascertainability criterion* requires that there be some methods by which, at least in principle, we can ascertain probability values. In other words, if it is impossible, in principle, to find out what the probability values are, the interpretation will be useless. Last, the *Applicability criterion* expresses the fact that we are seeking for a concept of probability that will have practical predictive significance.
27. Van Fraassen (1983, p. 310).
28. Van Fraassen (1980).
29. Here it is, thus, the modal element.
30. For a good report on the duality of probability see Hacking (1975).
31. Carnap (1970a, p. 445).
32. Carnap (1970a, p. 445).
33. Indeed, it would be quite redundant to ask whether degrees of belief employed in personalistic interpretations really – i.e., *physically* – exist.
34. De Finetti (1993, pp. 348 ffw).
35. Nevertheless, it would still be possible to ask: what kind of subjectivist? After all, a subjectivist as van Fraassen based his personalistic account on frequencies.
36. Salmon (1967, p. 128), italic in the original.
37. van Fraassen (1980, p. 194).

REFERENCES

Carnap, R.:1970a, Statistical and Inductive Probability. In Brody (ed.), *Readings in the Philosophy of Science*. New Jersey: Prentice-Hall, 440–450.
Carnap, R.:1970b, On Inductive Logic. In Brody (ed.), *Readings in the Philosophy of Science*. New Jersey: Prentice-Hall, 451–477.
Carnap, R.: 1971, *Logical Foundations of Probabilities*. Chicago: University of Chicago Press. 2nd print, 4th imprint.
Churchland, P. and C. Hooker (eds.): 1985, *Images of Science: Essays on Realism and Empiricism*. Chicago: University of Chicago Press.
De Finetti, B.:1993, Probabilità e induzione. Induction and Probability, a cura di Montanari D. e Cocchi D., Bologna, CLUEB.
Hacking, I.:1975, *The Emergence of Probability*. Cambridge: Cambridge University Press.
Salmon, W.C.: 1967, *The Foundations of Scientific Inference*. Pittsburgh: University of Pittsburgh Press.
Salmon, W.C.: 1968, Who needs Inductive Acceptance Rules, In Lakatos (ed.), *The Problem of Inductive Logic*. Amsterdam: North-Holland, 139–144.
Salmon, W.C.: 1984, *Scientific Explanation and the Causal Structure of the World*. Princeton: Princeton University Press.
Salmon, W.C.: 1985, Empiricism, the Key Question, Rescher, *The Heritage of Logical Positivism*. Lanham: University Press of America, 1–22.
Salmon, W.C.: 1990, *Four Decades of Scientific Explanation*. Minneapolis: University of Minnesota Press.
Suppe, F. (ed.): 1977, *The Structure of Scientific Theories*. Urbana: University of Illinois Press.
Suppe, F.:1989, *The Semantic Conception of Theories and Scientific Realism*. Urbana: University of Illinois Press.
van Fraassen, B.: 1980, *The Scientific Image*. Oxford: Clarendon Press.
van Fraassen, B.:1983a, Calibration: A Frequency Justification for Personal Probabilities. In Cohen and Laudan (eds.), *Physics, Philosophy and Psychoanalysis*. Boston: Reidel Publishing Company, 295–319.
van Fraassen, B.: 1983b, Theory Confirmation: Tension and Conflict. In Weingartner and Czermak (eds.), *Epistemology and Philosophy of Science: Proceeding of the 7th International Wittgenstein Symposium*. Vienna: Hoelder-Pichler-Tempsky, 319–330.
van Fraassen, B.: 1989, *Laws and Symmetry*. Oxford: Clarendon Press.
van Fraassen, B.: 2000, The False Hopes of Traditional Epistemology. *Philosophy and Phenomenological Research* 60: 253–280.

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