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Bayesianism and the Idea of Scientific Rationality

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Bayesianism has been dubbed as the most adequate and successful theory of scientific rationality. Its success mainly lies in its ability to combine two mutually exclusive elements involved in the process of theory-selection in science, viz.: the subjective and objective elements. My aim in this paper is to explain and evaluate Bayesianism's account of scientific rationality by contrasting it with two other accounts.

Keywords: Bayesianism, historiographical theory of science, scientific rationality, rational reconstruction program.

1. *The Problem of Scientific Rationality*

The problem of scientific rationality is one the most important problems in philosophy of science. Throughout its long and colorful history, the problem has seen many formulations. However, there seems to be an essential theme that remains the same in all those varying formulations. This can be formulated as follows: "Does the choice of a particular scientific theory over another involve rationality?" Notice that the concept of rationality figures prominently here. It is, thus, important to show what it means.

When we talk about rationality in the problem of scientific rationality we are talking about the rationality involved in choosing one theory over another; i.e. we are talking about the conditions that constitute the reasonableness of such a choice. Let me elaborate on this further. Suppose that we have two rival theories, X and Y, trying to describe the *same* phenomenon. X and Y are not reducible to one another, since the set of statements, which makes up X, could not be subsumed to Y, and vice-versa. Suppose further that the scientific community chooses X over Y. The issue here is whether those scientists really have *good* reasons to choose X over Y, and if they have, what conditions then would constitute the choice's reasonableness.

On the one hand, some philosophers hold that a choice's reasonableness is simply determined by a strict methodological process. They claim that there are procedures and criteria in determining whether a theory is better than another. Others claim, on the other hand, that the reasonability of a choice is more complex than that. They claim that scientific rationality can only be explained by looking at arbitrary elements present in the processes involved in scientific enterprise as a whole. The issue about scientific rationality, therefore, is concerned with explaining the conditions that constitute the rationality of the theory-selection process in science. Before discussing this further, there is a much pressing matter that I need to address first.

Some philosophers have objected to the idea of characterizing the problem of scientific rationality only in terms of the rationality of the theory-selection process. They claim that this idea is founded on a faulty assumption. They contend that since the process of theory-selection is only one of the activities done in the sciences, it would not follow that if this were irrational, the whole scientific enterprise would then be irrational. For them, the whole debate about scientific rationality falsely assumes that the rationality of science as a whole is seen only in the theory-selection process.[1]

Like many other philosophers dealing with scientific rationality, I do not deny that the theory-selection process is just another activity done in the sciences. I need to emphasize, however, that the epitome of the scientific enterprise is seen in this process. The rationality of the whole enterprise is best seen in the manner by which the scientific community decides what theories to accept or reject. If their choice were made unreasonably, it puts into question the entire scientific enterprise. On the other hand, if it was proven otherwise, then it reassures us of the confidence that we give to science. The reason why the problem of scientific rationality, as is characterized here, focuses on the debate concerning the rationality of the theory-selection process is not only because it is the epitome of the scientific enterprise, but also because it assures us of the confidence that we give to science as a whole.

2. *Two Alternative Solutions*

There are two very influential solutions to the problem of scientific rationality. There are those who claim that the choice of a scientific theory is determined by strictly following a method. For others, such a choice is ultimately determined by reasons external to science itself—be it personal, social, or political. Adherents of the former solution are influenced by logical empiricism's rational reconstruction program; adherents of the latter are influenced by Kuhn's historiographical theory of science.

[1] For example, Siegel (1985) has argued that the issue concerning the rationality of the process of theory-selection presupposes an answer to the question, "In what constitutes rationality in science?" He claims that this question is prior to the question formulated in this paper. I shall argue against this claim.

For a long time, the rational reconstruction program has been the standard conception of scientific rationality. Adherents of this program not only include the logical empiricists, like Schlick and Carnap, but also the Popperians—supporters of Popper—and the later neo-pragmatists, like Quine and van Fraasen. By considering the following theses, we could have an idea of the rational reconstructionist's solution to the problem of scientific rationality:[2]

(1) the thesis of the unified method of science
(2) the thesis of formalizability of this method
(3) the demarcation thesis; and,
(4) the thesis of scientific rationality.

The first thesis tells us that by looking at the history of science, one would find some semblance of a unified scientific method. The second states that it is possible to formalize or systematize this method, and it is the philosopher's task to do so. Through the second thesis, the third thesis states that this formalized scientific method differentiates science from the non-sciences and the pseudo-sciences. Still via the second thesis, the fourth thesis tells us that such a method could show how science really works. That is, how scientific theories are made, how they are accepted, and whatnot.

From the four theses, we could already have an idea how the rational reconstructionist would answer the problem of scientific rationality. The solution is roughly this. Given two opposing theories, X and Y, scientists *would* choose X over Y if and only if (iff) using the formalized scientific method, X is shown to be better than Y. The idea is that this formalized scientific method would give adequate reasons to prefer one theory over the other. The process of theory-selection, therefore, would only be a matter of following the rules set by this method. But what is this method?

There are two competing "methods" available for the rational reconstructionists: the method of confirmation and the method of falsification.[3] The method of confirmation works as follows. Scientific inquiry usually starts with a theory. If predictions or descriptions made using this theory were shown to be true by some (either observational or experimental) evidence, then such a theory would thus be confirmed, or at least shown to be empirically adequate. In light of the problem of scientific rationality, this method works as follows. Given two opposing theories, X and Y, if the gathered evidence shows that X's descriptions are true, and shows Y's to be false, it would then warrant the choice of X over Y. Because of this simple formula for theory-selection, many

[2] I am following the discussion of these four theses in (Jiang 1985).

[3] It should be noted, however, that there is a deep tension between these "methods" of science. Proponents of the method of confirmation, like Hempel, claim that this method is a more powerful method than the method of falsification. Proponents of the other camp, like Popper, make the same claim in favor of their preferred "method".

rational reconstructionists were led to believe that the method of confirmation is the best method for science. Others, like Popper, were not quite impressed by this.

Popper has showed that if the method of confirmation were the real method of science, then theories like astrology and alchemy would have to be accepted as scientific theories, since this method could easily be applied to them. Of course, rational reconstructionists would repudiate this idea because, for them, these "sciences" are *not* really scientific. Since the method of confirmation would consider such theories as scientific, Popper claims that it is the wrong method of science. What he proposes as an alternative is the method of falsification.

The method of falsification assumes that theories can never really be confirmed; rather, they can only be *temporarily* corroborated by certain evidence. Like the method of confirmation, the method of falsification sees that scientific inquiry begins with a theory. However, unlike the former, the latter obliges scientists to look for evidence that could show that their theory is false—since the true mark of a scientific theory is its falsifiability (possibility to be false). If the lot of evidence were to show that the theory is false, then it would have to be rejected. If otherwise, then it is said to be corroborated by such evidence. Nothing is final here. Some accepted theory might eventually be rejected—due perhaps to some new evidence against it. But this should not cause dismay, for this process is the mark of "scientific progress." In light of the problem of scientific rationality, the method of falsification works as follows. Given two opposing theories, X and Y, X is chosen over Y iff X and Y are falsifiable and X is corroborated by certain evidence, while Y is not. If X is later shown to be false by some new evidence, and another theory, Z, which is falsifiable but is now corroborated by that new evidence, Z should be chosen over X.

For rational reconstructionists, therefore, scientific rationality is determined solely by the method of science. On the basis of evidence, theories are accepted or rejected. The manner by which theories are accepted or rejected depends either on how evidence corroborates or confirms them. There are three important elements in this account of scientific rationality. First, theories should be *about* something empirically testable. Second, evidence that confirms or corroborates *should* be external to the theory. Third, confirmation (or corroboration) determines the acceptance or rejection of a theory. Only by following the method of science could we show how scientific rationality is possible. Friends of the rational reconstruction program have thus shown that there can only be an *objective* way of answering the problem of scientific rationality.

Kuhn, a leading proponent of the historiographical theory of science, has raised crucial objections against the rational reconstruction program's solution to the problem of scientific rationality. First, he sees that the picture of the history of science proposed by the rational reconstructionist is normative rather than descriptive. He argues that if we were to look at the actual history of science, we would not see a unified method that governs scientific growth; what we would see, rather, are "non-cumulative developmental episodes in which an older paradigm is replaced…by an incompatible new one" (Kuhn 1996, 92). Since the first thesis espoused by rational reconstructionists tells us that a unified method of science can be seen in the history of science, and if Kuhn's observations are correct, then this rational reconstructionist thesis would be false. What then is the intellectual force of such a thesis? For Kuhn, since this thesis is false, it would mean that the rational reconstructionist's insistence for a method of science would merely be an imposition of a dogma. If this were the case, it would then follow that their clamor for a method of science would be circular, thus making the "method" of science questionable.

Second, Kuhn points out that the rational reconstructionist's depiction of scientific rationality is limited. That is, their thesis of scientific rationality does not provide a complete description of the scientific process. For rational reconstructionists, the process of choosing a *theory* over another would simply be a matter of strictly following the method of science. However, Kuhn points out that this view only applies to a specific period in the history of science, which he calls "normal science", and not to whole history of science. Kuhn defines "normal science" as "research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice" (1996: 10). Since normal science is based on the scientific community's acknowledgment of these past achievements, a particular way of doing science is thus born. This way of doing science is what Kuhn calls a "paradigm".

For Kuhn, a paradigm functions like the rational reconstructionist's view of the method of science. It determines what evidence would be acceptable in confirming a theory, or what research topic should be undertaken in perfecting a theory. This determination, however, is only made within this dominant paradigm. Kuhn further points out that in the actual history of science there were episodes where this paradigm breaks down due to some anomalies that could not be accounted by the dominant paradigm. The break down of a paradigm is what he calls, "crisis science". In crisis science, the scientific community suffers a terrible fate because the dominant paradigm is put into question. Without this paradigm, normal science would cease its activities. Kuhn argues that although some scientists would try to save the old paradigm, in the time of crisis many would offer new paradigms to account for the anomalies that the old paradigm could not. In this period, the whole scientific enterprise would have many different paradigms. But crisis science would eventually end. Its end is marked by the "emergence of a new candidate for paradigm and with the ensuing battle over its acceptance." (Kuhn 1996: 84). The problem, then, is to determine the conditions and processes involved in choosing one paradigm over another.

To paraphrase Kuhn, it is impossible to use the rational reconstructionist's idea of the method of science as a standard of rationality of choosing one paradigm over another "for these (methods) depend in part upon a particular paradigm, and that paradigm is at issue." (1996: 94). Kuhn further claims that to resort to a "method" in choosing between paradigms is circular since "[e]ach group uses its own paradigm to argue in that paradigm's defense" (1996: 94). Thus, Kuhn shows that the rational reconstructionist's main theses are problematic. And since they are problematic, their solution to the problem of scientific rationality would be problematic as well.

Kuhn's alternative account of scientific rationality is somewhat controversial. He sees scientific rationality not as a matter of simple rule-governed processes, but a more complex one.[4] For Kuhn, science is a *human* endeavor. As such, there are elements in it that color the way science is conducted. Since science is a human endeavor, it follows that scientific rationality is also marked by these *humanistic* elements. For Kuhn, "[a]n apparently arbitrary element, compounded of personal and historical accident, is always a formative ingredient of the beliefs espoused by a given scientific community in a given time" (1996: 4). The combination of this arbitrary element and the personal niceties of scientists make the problem of scientific rationality a human issue. In this picture, scientific rationality is an ongoing process that starts from the formative years of the members of a scientific community, up to their activities in specific fields, then to their decision to accept or reject theories, and then to the process of relearning or unlearning old ways of thinking. Furthermore, this process informs the way that a scientist chooses anything. A scientist's background would influence his preferred area of research. A group of scientists' shared commitments would determine their choice of accepting the results of an experiment.

In general, for Kuhnian historiographers of science, scientific rationality—and the rationality of choosing one theory over another—depends on arbitrary elements external to the logic and method of science, or even to the facts observed. Thus, these apparent arbitrary elements also determine the theory-selection process. Such a process is founded upon certain value-laden reasons and commitments shared by the members of a scientific community. These reasons are not derived from any method of science, but are more political or social in nature. To put it roughly, the Kuhnian idea of scientific rationality with regard to theory-selection is this. Given two opposing theories, X and Y, X is chosen over Y iff a *consensus* to choose X over Y is reached by the members of the scientific community.

This does not mean that a theory is selected by mere majority vote

[4] In what will come next, I have refrained from articulating certain Kuhnian themes, like revolutionary science, changes of worldview, and incommensurability of theories as these are not deemed necessary to articulate the historiographical theory's main thesis.

or by a shared whim. Rather, members of the scientific community *eventually* arrive at a choice because of the values and commitments they share, like valuing the consistency and plausibility of the theory, or the commitment to scientific development, etc. It is not the case, however, that the sharing of values and commitments means that the assignment of importance of values or commitments is the *same* for each member of the community. This is not possible because each individual, informed by their personal backgrounds, would assign levels of value differently. Only by having these different subjective values meet could a consensus be produced. Kuhn's historiographical view of science gives much importance to these *subjective* values because these have "an important effect on scientific development" (ibid). But this emphasis on subjective values is not without problems.

Many philosophers have argued that Kuhn's emphasis on subjective values makes the whole theory-selection process a highly subjective affair. Kuhn does not deny this; in fact he embraces it. Subjectivity drives science to progress. Without it, science will be impossible. On the other hand, others have argued that if Kuhn's view is correct, then it would show that whole scientific enterprise would be irrational. Kuhn counters that this objection is only tenable if rationality *means* strictly following a rule or method; but as we have seen, he denies that there is such a method.

One very important objection against Kuhn's historiographical view is the fact that, contrary to Kuhn's point, the process of theory-selection involves *evidence*. Kuhn's account focuses too much attention on the historical aspects of science that the question of evidence has been overlooked. Why is it that although there are subjective elements that strongly influence a scientist's acceptance of a theory, the very same scientist would, more often than not, accept a theory on the basis of compelling evidence for it, even if such evidence is contrary to his personal beliefs? This is a feature of scientific rationality that Kuhn's view fails to give a judicious account.

3. *Bayesianism*

The main project of the Bayesian approach to scientific rationality is to combine the rational reconstructionist's insistence for an *objective* method of determining a choice's reasonableness with Kuhn's emphasis on the importance of *subjective* arbitrary elements that influence the members of the scientific community. There are three important elements here that need to be considered:

(1) a subjective interpretation of probability statements[5];
(2) the Dutch book argument; and,
(3) Bayesian thesis of rationality.[6]

With these three elements, Bayesianism does not only give an adequate theory of scientific rationality, but also restored the importance of evidence and confirmation in the theory-selection process.

Bayesianism begins with a subjective interpretation of probability. On this view, probability statements are statements about personal degrees of beliefs.[7] These degrees of beliefs are quantifiable according to a 0 to 1 scale, 0 being the lowest value and 1 being the highest. The assignment of these values is a highly personal, thus subjective, affair. A person can freely assign a value of .70 to his belief that he will win the lottery, regardless of whether he has strong grounds for it. The only restriction that Bayesianism imposes on the assignment of values is the coherence of this assignment with other beliefs. Since the assignment of values is too subjective, then there would be a problem of determining coherence, since we can have a coherent set of irrational beliefs. To answer this problem, Bayesianism has the Dutch book argument.

The Dutch book argument is a pragmatic test for the coherence of degrees of beliefs. In its simplest formulation, it states that if a person should be willing to act in accordance to his beliefs. However, if the result of his action would make him suffer more losses than receive more gains, then his beliefs are incoherent, and he is acting irrationally; otherwise they are coherent, and he is acting rationally. For Bayesians, the coherence of beliefs is a matter of a betting game.

[5] There are three dominant interpretations of probability statements: *a priori* (classical) interpretation, relative frequency interpretation, and the subjectivist interpretation. The classical interpretation, developed by the "fathers" of probability theory, Fermat and Pascal, tells us that probability statements are statements about the chances of some favorable outcome happening over the total number of *possible* outcomes. Thus, the statement, "There's a 25% chance that I'll get a clubs from a standard deck of cards" means that of the fifty-two cards, there are thirteen chances of having a favorable outcome. On the other hand, the relative frequency theory, developed by Keynes, claims that probability statements are statements about the number of instances that a favorable outcome happens over an observed period of time. Thus, the statement, "There's a 30% chance that I'll get six in a single roll of a loaded die" means that out ten times that I rolled that die, three turned up six. The subjectivist interpretation, developed by Ramsey, sees probability statements as statements about a person's partial beliefs. Thus, the statement, "There's a 20% chance that I'll get the job" means that the person who uttered the statement sees that there's a low chance for him to get the job. For further discussions on the interpretations of probability, see (Hajek 2012).

[6] Bayesianism is considered as a general theory of rationality, see (Joyce 2004). But although this is the case, it does not prohibit extending its use to account for scientific rationality.

[7] Ramsey is acknowledged as the first to discuss the philosophical underpinnings of a subjective interpretation of probability statements, see the collection of his works in (Ramsey 1996).

Suppose that person, A, assigns .51 to belief, B, and assigns the same value to a contrary belief, not-B. Suppose further that someone offered him a wager to the effect that A bets $6 on B and another $6 on not-B. If B obtains, A will win $10; if not-B obtains, he'll also receive $10. Suppose that either B or not-B will obtain, but not both. If A decides to bet on both B and not-B, then we will know that he has an incoherent set of beliefs, since he is willing to lose $12 only to gain $10.

The Dutch book argument shows that the coherence of a set of beliefs, hence also the rationality of the person having those beliefs, can be determined if that person is not willing to lose more than he could gain. If the person decides to act according to his incoherent beliefs, then he is acting irrationally. Notice here, that the argument works on two assumptions. First, rationality of choices involves coherence of beliefs, which in turn presupposes the notion of utility expectations; second, there are external elements that determine the coherence of beliefs. These two aspects are very important in Bayesianism's account of scientific rationality.

External elements, like observational or experimental evidence, are important in determining rationality of choices. Although, Bayesians are willing to grant that the assignment of values is subjective, they also believe that it is important to look at external objective factors that determine a choice's rationality. Objectivity is founded on a formalized notion of *confirmation*. It is formulated as follows. A certain evidence, E, *confirms* a person's subjective assignment of degrees of belief, P(B), just in case E raises P(B). That is, P(B/E) > P(B). Otherwise it is disconfirmed. Confirmation happens on the level of the subject involved. Via a subjectivist interpretation of probability, a person assigns a value to his belief. If some evidence confirms this belief, then this evidence raises his confidence to his belief. There is an implicit appeal to conditional probabilities here. That is, if E confirms P(B), then E *raises* P(B).

The formalized idea of confirmation has the Bayesian theory of rationality as a necessary consequence. This is formulated as follows: P(T/E) = P(E/T) x P(T)/P(E).[8] What this formula means is simply that a theory is more confirmed by unexpected evidence than expected ones.

[8] Where P(T/E) means that the degree of belief to a theory given the evidence; P(E/T) expresses *a measure* that that the evidence is unsuprising given the theory; P(T) means the degree of belief to a theory prior the evidence; and P(E) means the prior probability of evidence. Because of limited space, I could not unpack the niceties of this formula. However, I'll try to discuss the two principles involved here: (1) the prediction (expectation) principle; and (2) the surprise principle. The prediction principle states that if a person assigns a high value to the belief that some evidence, E, would occur because of a theory, T, then E *strongly* confirms T if E thus arise. The surprise principle, on the other hand, states that if a person is expecting two evidences: E and E* from T, if E is more surprising than E*, but would not be surprising if T were true, then E *strongly* confirms T than E* does. These two principles show that unexpected evidence that a theory predicts strongly confirms that theory than expected evidence could. For further details of the formulation, see (Joyce 2004).

Thus, if some evidence strongly confirms a theory, I *should* then assign a higher value to my theory given the evidence.[9] The importance of this result can be seen more clearly if we apply it in relation to the problem of scientific rationality.

The Bayesian account of scientific rationality—especially of the rationality of choice—amounts to the following. If two theories, X and Y, predict that some event, E, is *expected* to happen, and E does happen, then X and Y are *confirmed* by E. Of course confirmation here still relates to the raising of subjective degrees of beliefs. But if X predicts a further *unexpected* event F, which Y did not predict, and F does happen, given this *unexpected* evidence, one *should* raise the degree of belief to X than Y given F. As the Bayesian theory of rationality suggests, since some evidence raises our confidence to X than Y, then it should follow that we need to assign a higher value to X than Y. That is, X would be a reasonable choice than Y. Furthermore, given the Dutch book argument, if a person chooses Y over X given F, that person then is acting irrationally.

Bayesianism accounts for scientific rationality by considering two mutually exclusive elements in the theory-selection process: the subjective assignment of values to one's beliefs, and the objective confirming evidence of a theory. Bayesianism suggests that in choosing between two or more theories, it is always reasonable to choose the one which is *confirmed* by evidence. To choose otherwise is to succumb to the Dutch book argument.

4. *Conclusion*

I have discussed some of the intricacies of the philosophical debate about scientific rationality. I have shown that problem of scientific rationality is concerned with explaining the constitution of the rationality of choice in the sciences. Many philosophers have offered their solutions to it by maintaining either an extreme version of objectivism or subjectivism. The rational reconstructionists have espoused the former solution; while Kuhnians the latter. The rational reconstructionist's solution succumbs to Kuhn's historical critique. Kuhn's view, however, failed to recognize the importance of evidence in the theory-selection process. I have argued that Bayesianism offers a middle ground that reconciles both extreme positions. Armed with the subjective interpretation of probability, which highlights personal (subjective) assignment of values to beliefs, and the Dutch book argument, which is an objective test of the coherence of these assignments, Bayesians approached the problem of scientific rationality with a renewed interest on how evidence confirms a theory. As such, Bayesianism showed that although our beliefs are really subjective, we still have to choose the best theory

[9] Bayesianism is also characterized as a *normative* theory of rationality, see (Joyce 2004).

among other competing theories. And in having the notion of a "best" choice, we are already implying that we can have rational grounds for choosing one over the other. However, the rationality of this choice is not determined solely by a strict application of method or by mere personal arbitrary elements that surround our choices. The rationality of our choice of a theory is founded on evidence confirming that theory.

My main aim in this paper is to show that Bayesianism is indeed an adequate theory of scientific rationality. What I have discussed here are brief descriptions of the rational reconstruction program, Kuhn's historiographical view, and Bayesianism. Comparing the three, I have shown that Bayesianism reconciled the best aspects of the two other theories. As such, I can say that the Bayesian approach is indeed an adequate account of scientific rationality.

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References

Hájek, A. 2012. "Interpretations of Probability." *The Stanford Encyclopedia of Philosophy*, Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/win2012/entries/probability-interpret/>.

Jiang, T. 1985. "Scientific Rationality, Formal or Informal?" *The British Journal for the Philosophy of Science* 36 (4): 409–423.

Joyce, J. 2004. "Bayesianism." In A. R. Mele and P. Rawling (eds.). *The Oxford Handbook of Rationality*. Oxford: Oxford University Press.

Kuhn, T. 1996. *The Structure of Scientific Revolutions*, 3rd ed., Chicago: University of Chicago Press.

Ramsey, F. 1996. "Truth and Probability." In R. B. Braithwaite (ed.). *The Foundations of Mathematics and other Logical Essays*. London: Kegan, Paul, Trench, Trubner & Co.

Siegel, H. 1985. "What Is the Question concerning the Rationality of Science?" *Philosophy of Science* 52 (4): 517–537.