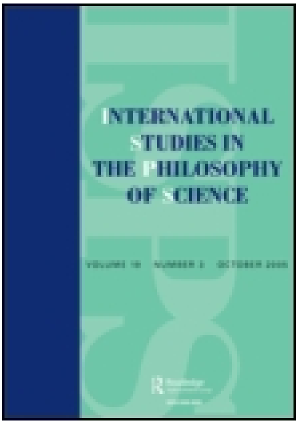

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Einstein's brand of verificationism

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James Robert Brown

No one better exemplifies the magic, mystery, and awesome might of physics than does Albert Einstein. The unruly hair, the baggy pants, the Germanic accent, these in the public mind are the characteristics of genius. For philosophers, too, he is a hero, for he seems distinctly like one of us when he declares that 'Science without epistemology is – in so far as it is thinkable at all – primitive and muddled.' (1949, p. 684) But the source of the appeal goes beyond this.

Einstein is something of a man for all seasons; we can find him catering to every philosophical taste. Those who like their physics done *a priori* are delighted to find in Einstein the old-fashioned rationalist who holds 'pure thought can grasp reality.' (1934, p. 274) But staunch empiricists can take heart, too, since he is also found holding that 'Pure logical thinking can not yield us any knowledge of the empirical world; all knowledge of reality starts from experience and ends in it.' (1934, p. 271) For a very long time an empiricist picture of Einstein had been dominant. The reason for this, aside from the odd remark Einstein himself made, has largely been the way in which the theories of special and general relativity were presented; both smacked of verificationism. And even if Einstein did not make detailed specific philosophical pronouncements along positivist lines, that did not matter too much since, as Reichenbach put it, 'It is not necessary for him to elaborate on it . . . he merely had to join a trend . . . and carry [it] through to its ultimate consequences.' (1949, p. 290)

But this positivist picture has largely fallen by the way-side in the last few years. Now it is common-place to view Einstein as an empiricist in his early days and becoming a realist in his maturity. No one has done more to create this new and highly attractive picture than Gerald Holton who describes Einstein's philosophical development as 'a pilgrimage from a philosophy of science in which sensationalism and empiricism were at the center, to one in which the basis was a rational realism.' (1968, p. 219) And Einstein himself is completely obliging; in his 'Autobiographical Notes' he seems to paint the same developmental picture. There he remarks that Mach undermined his early naivety, but that he adopted the great Austrian

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philosopher–physicist's brand of positivism *only* in his youth; eventually he came to see its shortcomings and dropped it.

> It was Ernst Mach who, in his *History of Mechanics*, shook this dogmatic faith; this book exercised a profound influence upon me in this regard while I was a student. I see Mach's greatness in his incorruptible skepticism and independence; in my younger years, however, Mach's epistemological position also influenced me very greatly, a position which today appears to me to be essentially untenable. For he did not place in the correct light the essentially constructive and speculative nature of thought. (Einstein 1949, p. 21)

Others besides Holton attribute the developmental view to Einstein. Arthur Miller in his two recent major studies (1981, 1984) and Arthur Fine in his recent book (1986) are two prime examples. Fine provides an interesting contrast with Holton; both see Einstein 'turning away from his positivist youth . . .', as Fine puts it, 'and becoming deeply committed to realism' (1986, p. 123). Nevertheless, Holton sees this as a definite move in the right direction while Fine, on the other hand, tends to downplay Einstein's later realism and instead glories in his youthful empiricism. 'Einstein's early positivism and his methodological debt to Mach (and Hume) leap right out of the pages of the 1905 paper on special relativity. The same positivist strain is evident in the 1916 general relativity paper as well . . .' Fine leaves no doubt that he takes this anti-realism to be a great virtue, '. . . it would be hard to deny the importance of this instrumentalist/ positivist attitude in liberating Einstein from various realist commitments. Indeed, Fine continues, 'without the "freedom from reality" provided by his early reverence for Mach, a central tumbler necessary to unlock the secret of special relativity would never have fallen into place.' (1986, p. 122f)

The developmental view of Einstein is enormously attractive. It seems to do justice to Einstein's own autobiographical remarks, and even better, it fits in nicely with the temper of contemporary times. Let's face it; positivism is dead and, in spite of recalcitrants like Fine and van Fraassen, most of us are realists. Isn't it nice that the greatest scientist of the century is one of us? Oh yes, Einstein was a positivist in his early days, but he soon saw through it and became a scientific realist. It is hard not to be attracted to this picture. But there are problems with it.

Problems with the developmental picture

For all its appeal, the developmental account runs into difficulties on several fronts. Here are just some of the problems with thinking Einstein made a 'pilgramage' from positivism to realism:

1 One of the most convincing considerations for thinking Einstein was a positivist in his youth is the formulation of special relativity, with all its talk about rods and clocks, etc. But we must not forget that special relativity has lots of non-observable features; for instance, it postulates an infinite class of inertial frames, something very far from experience.

2 During the same *annus mirabilus* that he produced his paper on special relativity, Einstein also published his other two great works on Brownian motion (1905b) and light quanta (1905c). Later Einstein said of his Brownian motion paper that it 'convinced the skeptics . . . of the reality of atoms.' (1949, p. 49) This is hardly the work of a Machian positivist, yet it was produced at the same time as relativity.

3 The decline of empiricism has not had a detrimental effect on either special or general relativity. If these theories are indeed linked to empiricism as say phenomenological thermodynamics or behaviourism are linked to this philosophical outlook, then we might expect relativity to have fallen on hard times; but this is certainly not the case.

4 Developmentalists offer little or nothing in the way of an explanation for Einstein's change of heart. Holton suggests that Einstein's realism came about with a growing religiosity. He remarks on the 'connections that existed between Einstein's scientific rationalism and his religious beliefs,' and furthermore, that 'There is a close tie between his epistemology, in which reality does not need to be validated by the individual's sensorium, and what he [Einstein] called "Cosmic Religion".' (Holton 1968, p. 242f) But this is quite unhelpful, since Einstein was never very serious about religious matters – he tended to use religious metaphors, such as 'God does not play dice', the way athiests use 'God's eye point of view' – and anyway to say he was becoming spiritual is really nothing better than a slightly mystifying way of saying he became a realist.

5 Einstein's alleged new-found realism is used to explain his objection to quantum mechanics. However, this attempted explanation runs together two different senses of realism which I will explain below.

6 Holton sometimes makes Einstein out to be a non-verificationist even in 1905 when constructing his special relativity paper. He says of Einstein's principle of relativity that it was 'a great leap . . . far beyond the level of the phenomena' (1981, p. 89). Of course, it is possible to follow Elie Zahar on this when he remarks that 'while paying lip service to Machian positivism, scientists like Einstein remained old-fashioned realists'. (1977, p. 195) But then the developmental view is trivialized; the only change in Einstein is that by becoming an explicit realist he came to hold a more accurate view of what he had been doing all along. Further the cost of such an intepretation is considerable: we lose the explanatory power to account for various features present in much of Einstein's early scientific work, empiricist-like features which are definitely there.

7 Related to this is Holton's explanation for why Mach, much to

Einstein's surprise, denounced relativity. Holton thinks it was because Mach saw through it and realized just how realistic and anti-empiricist the theory of relativity actually was. However, thanks to the recent detective work of Gereon Wolters (1984) we now know that Mach's 'rejection' was actually the forgery of his son Ludwig Mach. So we no longer need to explain away Mach's antipathy; indeed, just the opposite.

8 Finally, and as we shall see, most importantly, there is no mention in the developmental account of Einstein's distinction between 'principle' and 'constructive' theories, a distinction which he seems to have thought quite important. It turns out that the theory of relativity is a principle theory while quantum mechanics is a constructive one. The illusion of a philosophical change from positivist to realist is fostered, I will suggest, by the fact that Einstein's philosophical remarks focused on relativity during the early part of his career while his attention changed to quantum mechanics in his maturity; this was not a change in philosophy so much as a change in the subject of interest.

In light of these problems, a quite different account of Einstein's philosophical views seems called for.

Principle and constructive theories

Einstein liked to distinguish between two types of theories in physics, *principle theories* and *constructive theories*. The latter type of theory is any kind of hypothesis or conjecture which is proposed to explain a wide variety of facts.

> They attempt to build up a picture of the more complex phenomena out of the materials of a relatively simple formal scheme from which they start out. Thus the kinetic theory of gases seeks to reduce mechanical, thermal, and diffusional processes to movements of molecules – i.e., to build them up out of the hypothesis of molecular motion. When we say that we have succeeded in understanding a group of natural processes, we invariably mean that a constructive theory has been found which covers the processes in question. (1919, p. 228)

A principle theory, on the other hand, starts with something known to be true (e.g. that the speed of light in a vacuum is constant) and then forces everything else to conform to this principle. Unlike constructive theories which are speculative, principle theories never try to explain anything.

> The elements which form their basis and starting-point are not hypothetically constructed but empirically discovered ones, general characteristics of natural processes, principles which give rise to mathematically formulated criteria which the separate processes or the

> theoretical representations of them have to satisfy. Thus the science of thermo-dynamics seeks by analytical means to deduce necessary conditions, which separate events have to satisfy, from the universally experienced fact that perpetual motion is impossible. (1919, p. 228)

Einstein goes on to contrast these two types of theory and tells us which type of theory relativity is.

> The advantages of the constructive theory are completeness, adaptability, and clearness, those of the principle theory are logical perfection and security of the foundation.
>
> The theory of relativity belongs to the latter class. (1919, p. 228)

I am going to use Einstein's distinction between principle and constructive theories to paint a different picture of his philosophical views than the one given by the developmental account. Einstein's verificationism applies only to his principle theories, not to his constructive ones where he was arguably some sort of realist. Thus, it is no surprise to see positivist sounding language in special and general relativity, but not in his work on Brownian motion or light quanta. In later life, Einstein *appears* to have dropped his early empiricism and become a realist. I shall maintain, however, that this sort of change in philosophical view did not really occur; indeed, there was very little change at all. Rather, what did happen was a change in focus; his early attention was on relativity, a principle theory, while later it was on quantum mechanics, a constructive theory. There was a change in his scientific interests, but Einstein's philosophical views remained fairly stable throughout his life.

I must add, however, that the distinction between principle and constructive theories is not a sharp one. If it is a useful distinction, and I think it is, it must be understood as somewhat fuzzier than Einstein might think. The distinction is perhaps best understood by analogy with the distinction between the observable and the theoretical. This latter distinction is not a sharp one either, but clear examples on either side of the boundary exist. Trees, rabbits, unicorns, and pointer readings are observable, while electrons, genes, phlogiston, and super-egos are theoretical. (Notice that unicorns are 'observable', but not 'observed' which is why we think there are none.)

Einstein characterizes principle theories as 'secure' and 'non-explanatory', while constructive theories are explanatory and highly conjectural, hence insecure. By rejecting a sharp distinction between principle and constructive theories, we in effect reject a sharp distinction between explanatory and non-explanatory theories, and between conjectural and non-conjectural theories. These considerations will come up again below.

Free creations of the mind

Einstein is famous, or as some would have it, infamous, for his resistance to the quantum theory. There are two responses people typically made to his resistance, (and to some extent there is a tension between those two responses.) One is to dismiss Einstein as an old dog who couldn't learn new tricks. The other response is to express puzzlement at Einstein's resistance, since it was thought that the quantum theory, after all, was just a natural result that same philosophical attitude that Einstein himself applied so successfully in the founding of relativity. This latter view is nicely illustrated in the exchange between Einstein and Heisenberg as recounted by Heisenberg himself:

> 'But you don't seriously believe,' Einstein protested, 'that none but observable magnitudes must go into a physical theory?'
>
> 'Isn't that precisely what you have done with relativity?' I asked in some surprise. 'After all, you did stress the fact that it is impermissible to speak of absolute time, simply because absolute time cannot be observed; that only clock readings, be it in the moving reference system or the system at rest, are relevant to the determination of time.'
>
> 'Possibly I did use this kind of reasoning,' Einstein admitted, 'but it is nonsense all the same. Perhaps I could put it more diplomatically by saying that it may be heuristically useful to keep in mind what one has actually observed. But on principle, it is quite wrong to try founding a theory on observable magnitudes alone. In reality the very opposite happens. It is the theory which decides what we can observe . . .' (Heisenberg 1971, p. 63)

The philosophical position which so startled Heisenberg was a theme Einstein returned to and stressed again and again over the years. Perhaps the first time it appears is in his address celebrating Plank's sixtieth birthday in 1918. Einstein's remarks here are worth quoting at length as he not only outlines a conjectural or hypothetico-deductivist way of doing science, but also takes up the inevitable underdetermination problem:

> The supreme task of the physicist is to arrive at those universal elementary laws from which the cosmos can be built up by pure deduction. There is no logical path to these laws; only intuition, resting on sympathetic understanding of experience, can reach them. In this methodological uncertainty, one might suppose that there were any number of possible systems of theoretical physics all equally well justified; and this opinion is no doubt correct, theoretically. But the development of physics has shown that at any given moment, out of all conceivable constructions, a single one has always proved itself decidedly superior to all the rest. Nobody who has really gone deeply

into the matter will deny that in practice the world of phenomena uniquely determines the theoretical system, in spite of the fact that there is no logical bridge between phenomena and their theoretical principles; this is what Leibniz described so happily as a pre-established harmony.' (1918, p. 226)

It is interesting to see Einstein coping with the underdetermination problem, and we must admire his optimism, if not his naivety.

In his most philosophically sustained work, 'Physics and Reality', which was written in the mid-1930s, Einstein outlines his view as follows:

> Physics constitutes a logical system of thought which is in a state of evolution, whose basis cannot be distilled, as it were, from experience by an inductive method, but can only be arrived at by free invention. The justification (truth content) of the system rests in the verification of the derived propositions by sense experiences . . . (1935, p. 322)

The style of reasoning which Einstein favours here, namely some sort of hypothetico-deductivism (H–D[1],) is one he was already employing in 1905. In the same 'Autobiographical Notes' in which he suggests he was a Machian, he also describes (correctly, I might add) his work in statistical mechanics. 'My major aim in this was to find facts which would guarantee as much as possible the existence of atoms of finite size.' (1949, p. 47) Einstein goes on to describe the argument.

> The simplest derivation [of what turned out to be Brownian motion] rested upon the following consideration. If the molecular-kinetic theory is essentially correct, a suspension of visible particles must possess the same kind of osmotic pressure fulfilling the laws of gases as a solution of molecules. This osmotic pressure depends upon the actual magnitude of the molecules, i.e., upon the number of molecules in a gram-equivalent. If the density of the suspension is inhomogeneous, the osmotic pressure is inhomogeneous, too, and gives rise to a compensating diffusion, which can be calculated from the well known mobility of the particles.

He then concludes,

> The agreement of these considerations with experience . . . convinced the skeptics . . . of the reality of atoms.' (1949, p. 47f)

There are several things to note in this passage. For one thing, Einstein describes himself as doing something quite anti-Machian in 1905, and so, *contra* Holton and Fine, he is clearly a realist in his youth. The second thing to note is that the atomic theory is a constructive theory, and that Einstein's reasoning is clearly H–D.

Many of Einstein's remarks, both to Heisenberg and in his various essays written in later life, are grist for Holton's mill. Einstein's final philosophical position seems far from anything Mach would approve of. It seems to include the rejection of verificationism and the adoption of some sort of realism. But such a conclusion is far too hasty. If we look back at Einstein's characterization of constructive theories we can see that he is simply calling for some sort of hypothetico-deductivism. This is especially clear in a letter Einstein wrote to his old friend Maurice Solovine (on May 7, 1952) in which he clarified his views with the help of a diagram.

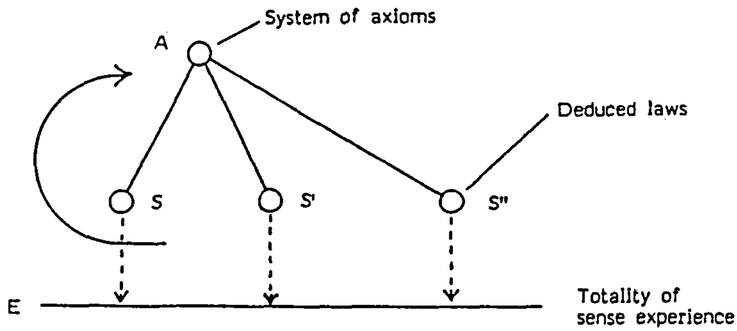

Figure 1

Much is made of this schema by both Holton (1979) and Miller (1984) who quite rightly note that Einstein thinks there is a great gap between experience and the axioms. But we should be careful about the circumstances under which Einstein thinks a jump should be made. On Einstein's distinction, it is made in constructive theories, not in principle ones. Miller misunderstands this distinction when he says Einstein 'leaped across the abyss between these (E) to invent (A), which comprises the two principles of special relativity'. (1984, p. 46) I want to pursue this, but before I do, a word about 'truth'.

Einstein's realism

For my purposes in this essay it is not very important one way or the other whether Einstein is a realist. Einstein's remarks cited above bear him out to be a hypothetico-deductivist. Holton, largely without argument, assimilates this with realism; but, of course, there is a considerable difference. One could hold with Duhem, for instance, that hypotheses are merely useful fictions – theories may employ any concept whatsoever; the only constraint is that they should 'save the phenomena'. Such an instrumentalism would be a far cry from a Machian positivism which barred all but observational entities, but it is certainly not realism.

I am presuming that Einstein is a realist about his constructive theories since I take it that the concepts which he liked to call 'free creations of the mind' are intended to refer and that the theories are actually true or false. However, this may not be so. 'It is difficult to attach a precise meaning to "scientific truth".' says Einstein, 'the word "truth" varies according to whether we deal with a fact of experience, a mathematical proposition, or a scientific theory.' (1929, p. 261)

Einstein does not elaborate sufficiently here, but we could imagine anti-realism creeping in: Observable 'facts' are 'true' in some ordinary correspondence sense while theories are 'true' only in the instrumental sense that they imply true facts. This seems also to be of a piece with remarks made many years later as part of his 'epistemological credo'.

> A proposition is correct if, within a logical system, it is deduced according to the accepted logical rules. A system has truth-content according to the certainty and completeness of its co-ordination possibility to the totality of experience. A correct proposition borrows its 'truth' from the truth-content of the system to which it belongs. (1949, p. 13)

Arthur Fine (1984) has with some justice recently challenged the view that Einstein is a regular scientific realist, but for my purposes here it does not matter very much one way or the other. The real issue is this: Did Einstein develop from a strict verificationism (in which there was a strict adherence to observable elements) to some sort of liberal H–D account (in which speculation and conjecture play a crucial role), and moreover, what was the character of his verificationism?

Relativity as a principle theory

Einstein repeatedly called relativity a principle theory. The starting point for such a theory, as he put it, is 'not hypothetically constructed but empirically discovered', and consequently has the 'advantage' of 'logical perfection and security of foundations.' (1919, p. 228) Throughout his life, Einstein characterized both special and general relativity as non-speculative, non-hypothetical, non-conjectural, in short, as principle theories rather than constructive ones.

Writing to his friend Conrad Habicht in 1905, and sending him the fruits of his labours of that marvelous year, Einstein called his light quanta paper 'very revolutionary', while he merely noted that the relativity paper might be interesting in its kinematical part. Years later, *after* he had quite explicitly embraced an H–D view, Einstein was still claiming that relativity had a kind of verificationist origin.

> I am anxious to draw attention to the fact that this theory [i.e., relativity] is not speculative in origin; it owes its invention entirely to the desire to make physical theory fit observed fact as well as possible. We have here no revolutionary act but the natural continuation of a line that can be traced through centuries.' (1921b, p. 246)

I want to contrast this with Einstein's H–D view of some theories, a view which is normally identified as his mature view, but which he actually put forward in 1919, two years *before* the verificationist sounding passage just cited.

> The supreme task of the physicist is to arrive at those universal elementary laws from which the cosmos can be built up by pure deduction. There is no logical path to those laws . . . (1919, p. 226)

It is clear from this pair of passages that Einstein is not passing from a Machian outlook to H–D, rather he is probably holding both views simultaneously. The H–D account applies to constructive theories and the Machian sounding sentiments apply to principle theories such as relativity.

Holton makes the same sort of mistake that Miller makes when he calls the thinking that went into special relativity 'a conjecture', and when he thinks of a constructive theory as 'one built up inductively from phenomena . . .' (1981, p. 88) Holton cites Einstein's remarks about the 'principle of relativity being raised to the status of a postulate' and calls it 'a great leap . . ., far beyond the level of the phenomena . . .' (1981, p. 89) This shows a misunderstanding of: first, what a constructive theory is; second, of what the difference between constructive and principle theories is; and third, of what sort of theory relativity is. Let us turn now to the details involved in relativity to clear up some of these confusions.

Einstein's brand of verificationism

Einstein's positivism seems to 'leap right out of the pages' as Fine put it. He begins the general relativity paper (1916) with the remark that in classical mechanics there is an 'epistemological defect . . . pointed out by Ernst Mach.' (1916, p. 112) Einstein then describes a thought-experiment with two globes which are in observable rotation with respect to one another. One is a sphere, the other an ellipsoid of revolution.

Einstein asks 'What is the reason for the difference in the two bodies?' He then sets verificationist conditions on any acceptable answer. I will quote at length, since the verificationism leads directly to Mach's principle and general co-variance.

> No answer can be admitted as epistemologically satisfactory, unless the reason given is an *observable fact of experience*. The law of causality has

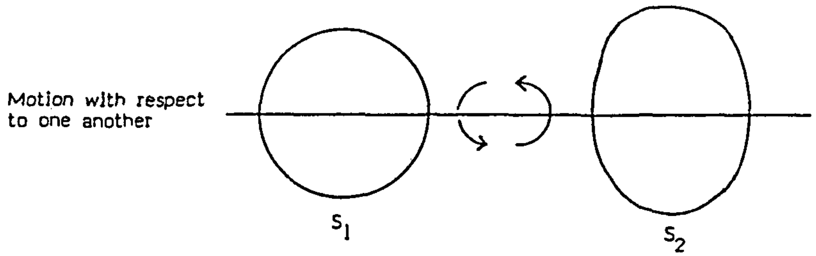

Figure 2

> not the significance of a statement as to the world of experience, except when *observable facts* ultimately appear as causes and effects.

Einstein then declares that classical physics is not up to epistomological standards.

> Newtonian mechanics does not give a satisfactory answer to this question. It pronounces as follows: The laws of mechanics apply to the space R_1, in respect to which the body S_1 is at rest, but not to the space R_2, in respect to which the body S_2 is at rest. But the privileged space R_1 of Galileo, thus introduced, is a merely *factitious* cause, and not a thing that can be observed. It is therefore clear that Newton's mechanics does not really satisfy the requirement of causality in the case under consideration, but only apparently does so, since it makes the factitious cause R_1 responsible for the observable difference in the bodies S_1 and S_2.

Einstein then goes on to say how things should be properly viewed, introducing both Mach's principle and the principle of general co-variance.

> The only satisfactory answer must be that the physical system consisting of S_1 and S_2 reveals within itself no imaginable cause to which the differing behaviour of S_1 and S_2 can be referred. The cause must therefore lie *outside* this system. We have to take it that the general laws of motion, which in particular determine the shapes of S_1 and S_2, must be such that the mechanical behaviour of S_1 and S_2 is partly conditioned, in quite essential respects, by distant masses which we have not included in the system under consideration. These distant masses and their motions relative to S_1 and S_2 must then be regarded as the seat of the causes (which must be susceptible to observation) of the different behaviour of our two bodies S_1 and S_2. They take over the role of the factitious cause R_1. Of all imaginable spaces R_1, R_2, etc., in any kind of motion relatively to one another, there is none which we may look upon as privileged *a priori* without reviving the above-mentioned epistemological objection. *The laws of physics must be of such a nature*

> *that they apply to systems of reference in any kind of motion.* (1916, p. 112f. Einstein's italics throughout.)

It is hard to resist the feeling that not only is this a strict form of empiricism, but that it is also doing a great deal of valuable work. Einstein may well have been in some regards an 'old-fashioned realist', as Zahar (1977, p. 195) says, but it is most doubtful that he is *merely* 'paying lip-service to Machian positivism'. There is a genuine Machian spirit to what is going on in both special and general relativity, and neither Einstein nor his commentators such as Holton and Fine are completely off target in describing it thus.

Of course, it seems absurd to see Einstein as both a realist and a verificationist simultaneously, but the tension is resolved when we see just what kind of verificationist he is.

Einstein's brand of verificationism is, in part, a type of *unificationism.* His positivism is more an impulse to unite, rather than to eliminate unobservable entities. The identification of gravitational and inertial mass is a case in point. Here we have a type of unification. It differs from what normally passes for unification: A theory which explains quite disparate phenomena is said to unify them. Such unification is also said to be evidence the unifying theory is true. However, this standard sort of unification, if it happens at all, is what goes on in Einstein's constructive theories. On the other hand, the unification which goes on in a principle theory like relativity is obviously different. It is a *stipulated*, not a *derived*, unification, so it has no evidential merits. But then this is no surprise since on Einstein's view a principle theory doesn't explain anything anyway.

Principle theories are not *intended* to be explanatory, but, of course, we know they are. Relativity explains a lot. Let us try an analogy: From straight-forward empirical observation I am prepared to assert: 'The letter is under the cup on the table.' This assertion is not intended by me to be explanatory, but it does have explanatory consequences anyway. For example, 'Why didn't the wind blow the letter away?' My assertion explains why. The situation in this everyday case and in special relativity are similar. Since every proposition has infinitely many consequences, it is bound to be explanatory for some of them. Thus, the distinction between principle and constructive theories cannot be sharp. Nevertheless, we would not want to say that 'The letter is under the cup on the table' is an explanation, at least not in the first instance; neither is special relativity.

Though the unification which goes on in a principal theory is a rather unusual sort of unification, it is also not the usual sort of verification either. The empiricism shines through because the unification applies, at least initially, to observable elements. But there is no requirement to banish the unobservable, as a thoroughgoing Machian would. Moreover, unification of whatever sort, cannot, of course, be the whole story. The principle of the constancy of light also plays a crucial role in special relativity, but there seems nothing about its postulation which has anything to do with unification.

I am well aware that my identification of Einstein's brand of verificationism with (in some cases) unification is anything but perspicuous. It is certainly less clear than the developmental view it wishes to replace. So let me try one more approach: Einstein's verificationism insists that theories should not distinguish between states when there is no observable difference between them. The magnetic induction example from the beginning of the special relativity paper (which I will look at briefly in a moment) perfectly illustrates this: There is no observable difference between the conductor moving while the magnet is at rest or vice versa, so only their relative motion should be taken into account. This kind of verificationism is different from the more traditional sort which insists on sticking to only observable elements when doing any sort of theorizing. Einstein is happy with all sorts of unobservable things. It also differs from any view that says there is no fact-of-the-matter to distinguish theories which are observationally equivalent.

The unification which is going on in principle theories manifests itself in the form of principles which are *imposed* upon everything else. This kind of theorizing is quite different than what typically happens in a constructive or conjectural theory. The consequences of constructive theories must agree with experience. A conflicting observation is a *prima facie* counter-example. But principle theories, on the other hand, ride roughshod over everything else. Special relativity does not explain Lorentz contraction, time dilation, or the relativity of simultaneity; it imposes these things everywhere. It is a framework, a Procrustean Bed, everything else is obliged to fit.

We can see the spirit of Einstein's verificationism at work in the opening paragraph of the special relativity paper.

> It is known that Maxwell's electrodynamics – as usually understood at the present time – when applied to moving bodies, leads to asymmetries which do not appear to be inherent in the phenomena. Take, for example, the reciprocal electrodynamic action of a magnet and a conductor. The observable phenomena here depends only on the relative motion of the conductor and the magnet, whereas the customary view draws a sharp distinction between the two cases in which either the one or the other of these bodies is in motion. For if the magnet is in motion and the conductor is at rest, there arises in the neighbourhood of the magnet an electric field with a certain definite energy, producing a current at the places where parts of the conductor are situated. But if the magnet is stationary and the conductor in motion, no electric field arises in the neighbourhood of the magnet. In

> the conductor, however, we find an electromotive force, to which in itself there is no corresponding energy, but which gives rise – assuming equality of relative motion in the two cases discussed – to electric currents of the same path and intensity as those produced by the electric forces in the former case. (1905a, p. 37)

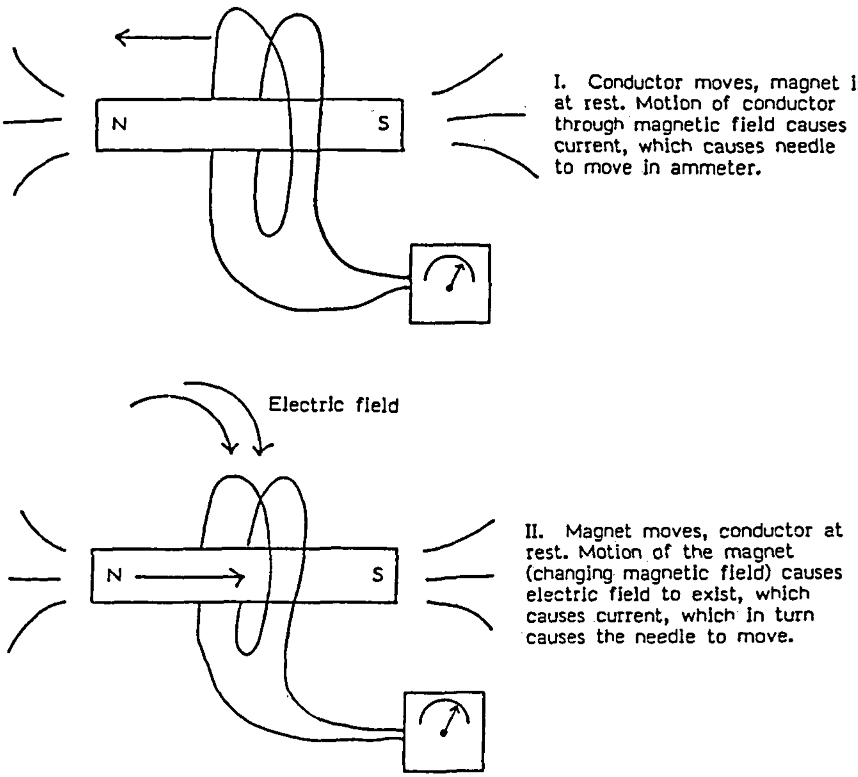

Figure 3

Einstein then goes on to say 'Examples of this sort . . . suggest that the phenomena of electrodynamics . . . possess no properties corresponding to the idea of absolute rest.' (1905a, p. 37) The principle of relativity is then 'raised to the status of a postulate.' (1905a, p. 38)

The crucial thing to note here is that Einstein does not rail against either fields or currents, neither of which are observable. In fact, in the magnetic induction example not only is the observable needle motion the same in both cases, but the unobservable current is the same in both cases, as well. The phenomena are identified as being the same phenomena in both cases; in other words, there is no distinction to be made in the observable realm, so our electrodynamic theory must adjust itself to this fact.

Einstein and Leibniz

It has often been claimed that Leibniz gave verificationist arguments against absolute space. It may prove instructive to contrast Einstein with Leibniz, since their respective verificationisms may be similar.

> . . . 'tis impossible there should be a reason why God, preserving the same situations of bodies among themselves, should have placed them in space after one certain particular manner, and not otherwise; why everything was not placed the contrary way, for instance by changing East into West. But if space is nothing else, but the possibility of placing them; then those two states, the one such as it, now is, the other supposed to be the quite contrary way, would not at all differ from one another. The difference therefore is only to be found in our chimerical supposition of the reality of space in itself. But in truth the one would be the same thing as the other, they being absolutely indiscernible; and consequently there is no room to enquire after a reason of the preference of the one to the other. (Alexander 1956, p. 26)

For Leibniz the indiscernibility which is at the heart of the issue is not mere *observable* indiscernibility, but some sort of complete indiscernibility. That is, all the theoretical apparatus in the world can be brought to bear on the question, and still there would be no way to distinguish two universes which are East-West reversed. This is no ordinary verificationism.

Einstein's brand of verificationism is perhaps much closer to Leibniz than to positivism. To see the difference let us contrast the Leibniz-Einstein brand of verificationism with that of a true positivist, Moritz Schlick who was one of the first philosophers to comment on relativity.[2] In his account of relativity which linked it to positivism, Schlick writes:

> . . . points which coincided at one world-point x_1, x_2, x_3, x_4 in the one universe would again coincide in the other world-point x_1, x_2, x_3, x_4. Their coincidence – and this is all we can observe – takes place in the second world precisely as in the first . . . The desire to include, in our expression for physical laws, only what we physically observe leads to the postulate that the equations of physics do not alter their form in the above arbitrary transformation . . . In this way Space and Time are deprived of the 'last vestige of physical objectivity,' to use Einstein's words. (1917, p. 53)

Unlike Schlick's, the Leibniz-Einstein brand of verificationism is one which most realists can happily live with. Of course, a realist about space-time will be unhappy, but theoretical entities are not *all* ruled out in principle, as they would be on Schlick's brand of verificationism. In each case, atoms, fields, or space-time will have to be argued for or against as the situation seems warranted. As it turns out, atoms and fields are OK as far as Einstein is concerned, but space-time, perhaps, is not. A true positivist would eliminate them all.

Experiments

Ilse Rosenthal-Schneider once asked Einstein a famous 'What if . . .' question. She was a student having a meeting with Einstein.

> Suddenly Einstein interrupted the reading and handed me a cable that he took from the window-sill with the words, 'This may interest you.' It was Eddington's cable with the results of the famous eclipse expedition. Full of enthusiasm, I exclaimed, 'How wonderful! This is almost the value you calculated!' Quite unperturbed, he remarked, 'I knew that the theory is correct. Did you doubt it?' I answered, 'No, of course not. But what would you have said if there had been no confirmation like this?' He replied, 'I would have had to pity our dear God. The theory is correct all the same.' (1980, p. 74)

Of course, it is easy to adopt such a confident stance when victorious; but what if things really had gone a different way? There is an example when the experimental outlook did not seem so good for Einstein; this is in the case of the Kaufmann experiments which were interpreted as refuting special relativity.

Kaufmann was a skilled experimenter working largely in the tradition known as the 'electromagnetic view of nature.' This was a school of opinion which flourished in the late nineteenth and early twentieth centuries. The central idea is that electromagnetism, not mechanics, is the real foundation of physics. Perhaps the most profound claim was that mass itself was electromagnetic in origin, being the result of a charged body interacting with the electromagnetic field. In such a context it would then be quite natural to ask whether mass varied with velocity, and if so, to what extent? Distinctions between longitudinal and transverse mass, which would be nonsense in classical mechanics, are perfectly meaningful here. Kaufmann performed a series of experiments on the relation between mass and velocity (see Miller 1981 for details) and the results were unfavourable to both Einstein and Lorentz.

In the very early days the two theories of Einstein and Lorentz were often identified; and Kaufmann rejected them together on the basis of his data. Their prediction for mass variation with velocity were at odds with his experimental findings. Lorentz's reaction is interesting. In a letter to Poincaré he writes, 'Unfortunately my hypothesis of the flattening of electrons is in contradiction with Kaufmann's results, and I must abandon it.' (Quoted in Miller 1981, p. 334.) Wouldn't Popper be pleased! Poincaré was almost as pessimistic, for him the principle of relativity was an experimental fact, but he was prepared to dump it.

Einstein, however, largely ignored Kaufmann's experimental results. Why? Holton paints a picture of the victory of a great theory over experience.

> With the characteristic certainty of a man for whom the fundamental hypothesis is *not* contingent either on experiment or on heuristic (conventionalistic) choice, Einstein waited for others to show over the next years, that Kaufmann's experiments had not been decisive. (1964, p. 190)

In another place Holton says that the Kaufmann experiments mask

> . . . the crucial difference between Einstein and those who make the correspondence with experimental fact the chief deciding factor for or against a theory: even though the 'experimental facts' at that time very clearly seemed to favor the theory of his opponents rather than his own, he finds the ad hoc character of their theories more significant and objectionable than an apparent disagreement between his theory and their 'facts'. (1973, p. 235)

Though they are somewhat at odds with one another, these two passages contain much insight. Nevertheless, I think they both miss the target. First, there is nothing in Einstein's work to suggest he really thought that the principle of relativity or the constancy of light postulate were 'not contingent on experiment'. He quite clearly states the contrary. And second, when Holton says that Einstein was put off by the *ad hoc* character of other theories, he is taking into account features of theorizing which have to do with constructive theories. When Einstein talked of 'inner perfection' (e.g., non-*ad hoc*) being a requirement, this is a requirement of a constructive theory. The epistemological status of relativity, as I have argued throughout, has quite a different character.

In contrast with the theory-over-experience interpretation of Einstein's reaction to Kaufmann, I instead suggest that it was a battle of (general) experience vs (particular) experience. It was not a case of clinging to a conjecture in the face of conflicting observations, but rather a case of clinging to one class of experiences (embodied in the principle of relativity and the constancy of light postulate) in the face of apparently conflicting low-level observations. As I said above, there is no sharp distinction between principle and constructive theories, so I cannot claim here that it was a clear case of observation vs observation, instead of theory vs observation. Nevertheless, Einstein's opposition to Kaufmann was much more like a case of one class of observations in conflict with another.

Einstein and Bohr

So far I have argued that: 1 There was no pilgrimage from Machian empiricism to some sort of realism; 2 Einstein maintained his (peculiar form of) verificationism throughout his life, and that it is tied up with what he called 'principle theories'; 3 Einstein simultaneously maintained an H–D, or conjectural methodology which was linked to what he called 'constructive theories'; 4 It is quite possible that Einstein was never at any time a genuine realist; 5 understanding Einstein's reaction to any 'refuting' experiment should always be viewed in the light of the principle/constructive distinction; 6 The illusion of a change in Einstein's philosophical outlook is perhaps largely due to a shift in his scientific interest from relativity, a principle theory, to quantum mechanics, a constructive theory.

Now it is time to say something about his attitude to quantum mechanics. As is well-known, Einstein intensely disliked it. Many were very surprised by his rejection. I have already mentioned Heisenberg above who was shocked that Einstein did not accept a line of reasoning (Only allow observables!) which Heisenberg took to be central to the success of relativity. Max Born, who despaired of ever getting Einstein on side, remarked that 'He believed in the power of reason to guess the laws according to which God has built the world.' (1956, p. 205) Einstein's deepest debate was with Bohr; it went on for years, but neither side budged. (See Bohr (1949).)

On the 'pilgrimage' view of Einstein, given by Holton, Fine, and others, Einstein's rejection of quantum mechanics is not in the least surprising: Einstein had become a realist, so he rejected quantum mechanic's self-imposed restriction to observable elements and instead posited a hidden reality which lay behind the phenomena.

I want to suggest a different way of looking at things. On my view Einstein would have been just as unhappy with quantum mechanics had he seen it in 1905 as he was in 1925 or 1955. Quantum mechanics is a constructive theory, and Einstein never had qualms about positing a hidden realm to explain the phenomena (e.g., molecules to explain Brownian motion).

When people express surprise that Einstein, who they thought to be a positivist, would not accept the (apparently) same line of reasoning in quantum mechanics as he did in relativity, they miss something important. But, on the other hand, by merely calling Einstein a 'realist', as Holton does, and using this to account for Einstein's opposition to quantum mechanics, Holton and others overlook a vagueness in the notion of 'realism'. The idea contains at least two distinct features.

If there was a change in Einstein's philosophical views from Machian empiricism to realism, then the difference was largely epistemological. To be a realist in this regard is to think we can have rational beliefs about a non-observable realm. It is in this sense that, for example, van Fraassen (1979) is an anti-realist; he is a skeptic about anything non-observable. This is *not* what is at issue in Einstein's quarrel with Bohr.

The other sense of realism is much more concerned with ontological or metaphysical issues; it is contained in the idea that the truth of a theory (or a single sentence) is *independent* of theorizers.[3] It is in this latter sense of realism that, say, Kant is an anti-realist. For him the truth of 'A causes B' or 'X is left of Y' fundamentally depend on rational agents. This, according to Kant, is the way we necessarily conceptualize our experience. However, there is no causation, nor are there spatial reasons among things-in-themselves.

The fight between Einstein and Bohr was over this ontological aspect of realism. On the so-called Copenhagen Interpretation of quantum mechanics, a measurement does not discover the magnitude of some system; rather it *creates* the result. Until a position measurement is made, an electron, for example, has no position at all. The Heisenberg Uncertainty Principle says in effect that if a position measurement is made, then there is no momentum at all. It is not that there is a momentum and we cannot know what it is; rather, there simply is no momentum. It was the violation of this aspect of realism which so troubled Einstein. On Bohr's view the world did not exist *independently* of our theorizing about it.

It is one thing to say Einstein developed from a Machian empiricism to accepting theoretical entities and the legitimacy of H–D methodology; but the battle against Bohr and quantum mechanics was more like a battle against Kant, a battle against the view that nature is dependent upon us. 'Physics', remarks Einstein, 'is an attempt to conceptually grasp reality as it is thought independently of its being observed.' (1949, p. 81) Such an outlook is perfectly compatible with the brand of verificationism I am attributing to him. Though I reject the developmental view, anyway; even if it were correct, it still would not explain Einstein's attitude toward quantum mechanics. Einstein is also famous for rejecting the alleged indeterminism of quantum mechanics, 'God does not play dice'. But the question of determinism is also independent of any verificationist vs H–D methodology debate.

Perhaps I have overstated things. A sharp distinction between epistemology and ontology is at the heart of the realist outlook. If Einstein had been a thoroughgoing Machian, the distinction would not have been appropriate to him. So it might be said that only by becoming a realist could Einstein make the appropriate distinction which in turn enabled him to criticise Bohr and other champions of the quantum theory.

This strikes me as a plausible view, and to some extent it is still in the spirit of the developmental account's version of events. Perhaps, then, the appropriately cautious thing for me to say in concluding this section is simply this: If we are looking for a nice, neat, straight-forward explanation of Einstein's rejection of quantum mechanics, we will *not* get it from his (alleged) development from empiricism to realism. I would prefer to look in an entirely different direction, though I am not sure just where.

Concluding remarks

I began by expressing dissatisfaction with several aspects of the developmental view. Even though Holton's 'pilgrimage' story has a happy ending – Einstein breaks free from appearances, marries reality, then rides off into the sunset – there are just too many lacunae in the story to make it believable. In its place I have given an account which takes his verificationism seriously; I see it as enduring throughout his scientific career and as doing very valuable work. But I also see it as compatible with a general realist outlook, even if Einstein was not himself a thorough-going realist.

There is perhaps a methodological lesson to be learned from Einstein. Normally realists hold some sort of H–D or broadly conjectural view of theorizing. Theories are believed true because of their consequences (i.e., explanatory power, novel predictions, etc.) Of course, in Einstein's terminology, these are constructive theories. For principle theories, like relativity, the story is quite a different one. Principle theories are fallible, but they nevertheless have quite a different feel about them than do the bold conjectures of his constructive theories.

I have used Einstein's own distinction between principle and constructive theories, not because I think historical characters should be allowed to tell their own stories – far from it. Rather, I have used it because it seems to capture a real distinction in genuine theorizing, a style that Einstein himself practiced so well. The onus is now, perhaps, upon us to spell out in greater detail the difference between principle and constructive theories and the workings of Einstein's brand of verificationism. It served us well, once; it may serve us well again.[4]

NOTES

1 I mean H–D to be understood very broadly: A conjectured theory is tested by its observable consequences. Popper, Lakatos, Laudan would all be examples of H–D methodology.
2 In his new work on space-time Friedman (1983) perceptively discusses Liebniz and Schlick in connection with Einstein.
3 See Newton-Smith (1982) for a discussion of various senses of realism.
4 I wish to thank P. Catton and K. Okruhlik for helpful comments as well as the audiences at Dubrovnik and McMaster where earlier versions were presented. I

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