A Neglected Route to Realism about Quantum Mechanics

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ABSTRACT

Bell’s Theorem depends on the assumption that hidden variables are not influenced by future measurement settings, and it is widely recognised that some of the puzzling features of quantum mechanics could be explained if this assumption were invalid. The suggestion has generally been regarded as outlandish, however, even by the taxed standards of the discipline. (Bell himself thought that it led to fatalism.) This paper argues that there is surprisingly little justification for this reaction. Using an informal model of the Bell correlations, the first part of the paper shows that the arguments against advanced action in QM, where not simply invalid, are easily evaded on good physical grounds. In the absence of such objections the approach has striking theoretical advantages, especially in avoiding the apparent conflict between Bell’s Theorem and special relativity.

The second part of the paper considers the broader question as to why advanced action seems so counterintuitive, by investigating the origins of our ordinary intuitions about causal asymmetry. It is argued that the view that the past does not depend on the future is largely anthropocentric, a kind of projection of our own temporal asymmetry. Many physicists have also reached this conclusion, but have thought that if causation has no objective direction, there is no objective content to an advanced action interpretation of QM. This turns out to be a mistake. From the ordinary subjective perspective, we can distinguish two sorts of objective world: one “looks as if” it contains only forward causation, whereas the other “looks as if” it involves a mix of backward and forward causation. This clarifies the objective core of an advanced action interpretation of QM, and shows that there is an independent symmetry argument in favour of the approach.

1 An early version of this paper was read at the AAHPSSS Conference in Melbourne in May, 1988. Many people have helped me with comments and discussion since then, and I am especially indebted to Jeremy Butterfield, Peter Menzies and Jack Smart. I am also grateful for research funding from the Australian Research Council.
The most profound conceptual difficulties of quantum mechanics are those that stem from the work of J. S. Bell in the mid-1960s. As Bell’s Theorem became well known, its author was often asked to survey the state of the subject, particularly in the light of his own contribution. He would typically conclude such a lecture by listing what he saw as possible responses to the difficulties, indicating in each case what he took to be the physical or philosophical objections to the response concerned. His intuitions in this respect were somewhat unfashionably realist—like Einstein, he disliked the common view that quantum mechanics requires us to abandon the classical idea of a world existing independently of our observations. He therefore appreciated the irony in the fact that from this realist standpoint, his own work seemed to indicate that there are objective non-local connections in the world, in violation of the spirit of Einstein’s theory of special relativity. As he puts it in one such discussion,

the cheapest resolution is something like going back to relativity as it was before Einstein, when people like Lorentz and Poincaré thought that there was an aether—a preferred frame of reference—but that our measuring instruments were distorted by motion in such a way that we could not detect motion through the aether. Now, in that way you can imagine that there is a preferred frame of reference, and in this preferred frame of reference things do go faster than light.

Bell reached this conclusion with considerable regret, of course, and would often note that there is one way to save both locality and realism. Bell’s Theorem requires the assumption that the properties of a system at a time are statistically independent of the nature of any measurements that may be made on that system in the future—“hidden variables are independent of later measurement settings”, to put it in the jargon. Bell saw that in principle one might defend a local (and hence special relativity friendly) Einsteinian realism by giving up this Independence Assumption. He found this solution even less attractive than that of challenging special relativity, however, for he took it to entail that there could be no free will. As he puts it, in the analysis leading to Bell’s Theorem

it is assumed that free will is genuine, and as a result of that one finds that the intervention of the experimenter at one point has to have consequences at a remote point, in a way that influences restricted by the finite velocity of light would not permit. If the experimenter is not free to make this intervention, if that also is determined in advance, the difficulty disappears. (Davies and Brown, 1986, p. 47)

It is surprising that philosophers have not paid more attention to these remarks. In effect, Bell is telling us that Nature has offered us a metaphysical

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2Bell (1964). Bell’s papers on the subject are collected in his (1987).
3In Davies and Brown (1986), pp. 48-9. The irony actually runs deeper than this, for Bell’s Theorem seems to undercut Einstein’s strongest argument in favour of his view that there is more to reality than quantum mechanics describes; more on this in section 1 below.
choice of an almost Faustian character. We may choose to enjoy the metaphysical good life in quantum mechanics, keeping locality, realism, and special relativity—but only so long as we are prepared to surrender our belief in free will! The philosophical interest of the case is hardly diminished by the fact that Bell himself preferred to decline the temptation. It would be fascinating enough if our philosophical engagement were merely that of spectators, an audience to Bell’s Faust. As it is, of course, the same metaphysical offer is extended to all of us, and many philosophers may feel that Bell was wrong to refuse. Some will have long since concluded that there is no such thing as free will, and might thus take the view that Nature is offering a very attractive free lunch. Others have become adept at juggling free will (or some acceptable substitute) and determinism, and hence might hope to take advantage of the offer at very little real cost. (With respect, after all, who is Bell to tell us what is incompatible with free will?) Even if Bell is right, and it does come down to a choice between a relativistically acceptable realism and free will, we might feel that Bell simply makes the wrong choice—what we should say, as honest empiricists, is simply that science has revealed that we have no free will.

At any rate, one of my aims in this paper is simply to bring this engaging issue to a wider philosophical audience. However, I also want to argue that the offer is a much better one than Bell himself believed. I want to show that we may help ourselves to the metaphysical advantages—locality and Einsteinian realism—but save free will. Roughly speaking, the trick is to reinterpret the same formal possibility in terms of backward causation. Instead of taking the prior state of the physical system in question to “constrain” the experimenter’s choice, we may reasonably take the latter’s choice to affect the prior state of the physical system. The mathematics thus remains the same as in Bell’s proposal, but we give it a different metaphysical gloss.4

The paper is in two main parts. The first part (sections 1-6) presents what might be called the first-order case for the backward causation approach. In

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4Strictly speaking there are two versions of Bell’s proposal. One way of relaxing the Independence Assumption is to take the required correlation between hidden variables and future measurement settings to be established by some common factor in their past. The other is to take the correlation to be sui generis, obtaining simply in virtue of the interaction between the system and measuring device in question. These two approaches agree on the “core” mathematics involved—on the nature of the correlation between hidden states and measurement settings—but disagree about the explanation of this correlation. It is the latter strategy that I wish to defend here. As I note in Price (forthcoming), its advantages may have been overlooked in part because it has not been clearly distinguished from the former strategy, or because the former strategy has seemed more plausible, in not countenancing backward causation. Bell seems to have been aware of both versions, and to have regarded both as incompatible with free will, but it is doubtful whether he saw them as clearly distinct. In my view the former strategy is objectionable on grounds that have nothing to do with free will, namely that it calls for a vast and all-pervasive substructure in reality to provide the required “common causes”. The latter view in contrast is elegant and economical, as compatible as need be with free will, and appears to respect a temporal symmetry that other views ignore.
the interests of accessibility, I begin with a very informal account of Bell's Theorem, and the EPR experiment on which it is based. I use a fictional model to illustrate the basic mathematical conflict between the kind of predictions made by quantum mechanics and those that Bell showed to follow from the plausible constraints of a local realism. Readers already familiar with the Bell's Theorem-by-parable approach will find nothing new here, and are encouraged to skim to section 3, where I use the model to explain how the formal possibility that Bell took to denies free will—the possibility that I recommend we interpret in terms of backward causation—provides an elegant resolution of the conflict. Section 4 shows how it avoids traditional objections to backward causation, section 5 discusses Bell's concerns about free will, and section 6 indicates how the informal discussion of the preceding sections applies to the real world—i.e., to quantum mechanics. The upshot seems to be that we may avail ourselves of Bell’s route to a local realism about quantum mechanics, provided that we are prepared to accept that quantum mechanics reveals the presence of backward causation in the world.

At this point in the discussion what is striking is that despite its evident advantages in quantum mechanics (and the weakness of the case against it), the backward causation approach still seems rather unpalatable. The second part of the paper attempts to diagnose and treat this aversion. Sections 7-13 develop a kind of second-order case for the approach, intended to clarify its consequences for physics and hence to show that it is very much more appealing than it seems at first sight.

One motivation for this second project is that because the relationship between causation and physical theory is itself obscure and philosophically problematic, it is very far from obvious what the backward causation proposal actually amounts to, in physical terms. Of particular relevance here is the fact that the temporal asymmetry of causation is itself rather puzzling, given the predominant symmetry of physical theory. As we shall see, this puzzle turns out to provide a useful entry point into the tangle of issues that needs to be unravelled, in order to clarify the physical content of the main proposal. In sections 7-9 I defend the view that the asymmetry of physical dependency—roughly, the fact that the future depends on the past but not *vice versa*—is anthropocentric in origin, a kind of projection of own temporal asymmetry. An attractive feature of this view is that it dissolves the apparent tension between the predominant temporal symmetry of physics and the asymmetry of dependency: since the latter isn’t objective, there is no conflict *in re*, as it were. The cure may seem worse than the disease, however, and much of the work in this part of the paper will be devoted to arguing that the view provides a sufficiently close approximation to objectivity to account for our intuitions concerning the direction of dependency.

All the same, the view that the direction of causation is not genuinely objective may seem rather a mixed blessing for my main project. It might explain our intuitive resistance to the idea of backward causation in quantum mechan-
ics, but doesn’t it throw the baby out with the bath water? If the direction of causation is not objective, what could be the physical content of the claim that quantum mechanics should be interpreted as revealing that some causation is “backward” rather than “forward”? Section 10 addresses this important objection, noting that the view that causal directedness is subjective leaves room for two sorts of objective correlational structures in the world. From the anthropocentric viewpoint one sort of structure looks causally “monotonic”, whereas the other permits a mixed interpretation, so that the temporal perspective of the interpreter imposes a dominant but not a universal causal orientation. This will give us a useful characterisation of the objective core of what might more accurately be called the advanced action interpretation. It simply amounts to the suggestion that the correlational structure of the microworld is of the latter (non-classical) kind. More surprisingly, we shall see in section 11 that this characterisation suggests a powerful symmetry argument in favour of the advanced action proposal—an argument which has been overlooked, I think, because it has been obscured by the more familiar asymmetry of dependency (rightly believed not to conflict with physical symmetry principles). Thus we shall be led to conclude that the advanced action approach is not only both physically and metaphysically respectable, but seems to have a striking advantage, over and above its application to quantum mechanics.

The paper also includes a brief account of an interesting new class of Bell-like results in quantum mechanics, which appear to yield similar conclusions to Bell’s Theorem by more direct means. I extend the parable of the earlier sections to describe these results in informal terms, and to make the point that they do nothing to weaken the case for advanced action in quantum mechanics—on the contrary, if anything, since they simply add new weight to the metaphysical burden from which advanced action promises to deliver us.

In case technically inclined readers should be disappointed, however, I want to make it clear at the outset that I am not offering the formal details of an interpretation or extension of quantum mechanics which embodies these ideas. I shall explain in informal terms how there comes to be a formal possibility of this kind—how it avoids the challenge to local realism posed by Bell’s Theorem. But my main concern is to show that the strategy is very much more appealing than Bell took it to be, and therefore worthy of a great deal more attention from both physicists and philosophers than it has received so far. My thesis is that an exceptionally promising route to a satisfying resolution of some of

\footnote{This enables us to clarify the assertion above that the backward causation interpretation has the same objective core as Bell’s own “no free will” model: both amount to the suggestion that quantum mechanics shows that what is in world is simply a particular pattern of correlations (a pattern that classical physics really had no business to exclude a priori. Whether we choose to interpret this pattern in terms of predetermined or backward causation thus turns out to be in an important sense beside the point—the brute physical facts are the same in either case.}

\footnote{A few physicists have been more attracted to the advanced action approach than Bell himself was. For references to some of their work, see the concluding footnote.}
the most profound puzzles in the history of science lies unexplored and almost unnoticed. The aim of this paper is to try to clear away some of the conceptual tangles that have obscured its promise for so long.

1. The man who proved Einstein was wrong

The most puzzling consequences of quantum mechanics arise in what are known as the EPR experiments. The crucial feature of these cases is that they involve a pair of particles, or physical systems, which interact and then move apart. Providing the interaction is set up in the right way, quantum theory shows that the results of measurements on one particle enable us to predict the results of corresponding measurements on the other particle. For example we might predict the result of measuring the position of particle 1 by measuring the position of particle 2, or predict the result of measuring the momentum of particle 1 by measuring the momentum of particle 2.

This was the feature that interested Einstein, Podolsky and Rosen in the famous (1935) paper in which they first drew attention to these cases. The paper sought to undermine what was already becoming the orthodox interpretation of the fact that quantum theory shows that it is impossible to determine accurately and simultaneously both the position and the momentum of a physical system. The orthodoxy—the “Copenhagen Interpretation”, as it came to be called—was that quantum systems do not have classical properties such as position and momentum, except when an appropriate measurement is made. Einstein wanted to argue that the restriction on measurement was merely epistemological, however. His motivation lay in his realism. He disliked the Copenhagen view that the nature of reality could depend on what humans choose to observe, and believed that the features of quantum mechanics that Bohr and others took as evidence of deep entanglement between observation and reality were really a reflection of the fact that the theory gives only a partial description of reality. As he saw, the crucial question is therefore whether the quantum mechanical description of reality can be considered to be complete. Does it say all there is to be said about a physical system, or are there further facts about the physical world not captured by quantum mechanics?

The two-particle systems seemed to provide the decisive argument that Einstein was looking for. With Podolsky and Rosen, he argued that the existence of such systems showed that quantum theory must indeed be incomplete. For if we can predict either the measured position or the measured momentum of a particle without interfering with it in any way, then it must have some property responsible for the results of those measurements. If we measure the position of particle 2 we infer that particle 1 has a definite position. If we measure the

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7This description of Bell is due to Gribbin (1990). In this article—a tribute to Bell following his death in October 1990—Gribbin gives a useful description of the EPR experiment and Bell’s contribution, and also mentions some of Bell’s remarks on the possibility of abandoning the Independence Assumption. For a comment taking issue with Gribbin’s characterisation of Bell in these terms, see my (1991a).
momentum of particle 2 we infer that particle 1 has a definite momentum. But since in neither case do we do anything to particle 1 itself, it must have a definite position and momentum, regardless of what we do to particle 2. In other words it must have properties not described by quantum mechanics. Quantum mechanics must be incomplete.

The EPR argument failed by and large to sway supporters of the Copenhagen interpretation, but this is perhaps due more to the obscurity of the Copenhagen response than to any compelling counter-argument it brought to light. With the benefit of hindsight we would probably now say that Einstein was right, had Bell not unearthed a remarkable sting in the tail of the EPR experiment. Einstein, Podolsky and Rosen had assumed that what we choose to measure on particle 2 could not have an effect on the distant particle 1. For example, measuring the position of particle 2 could not somehow “bring it about” that particle 1 had a definite position. In other words, the EPR argument for the incompleteness of quantum mechanics assumes that physical effects are local—that there is no action at a distance. The sting is that other features of the quantum mechanical description of certain EPR cases seem to show that any more complete (“hidden variable”) theory would have to be non-local. It would have to reject the very assumption on which the EPR argument depends. Einstein’s allies thus find themselves in an unfortunate dilemma. To make a hidden variable theory work—to make it consistent with quantum mechanics—they have to abandon the assumption that enabled them to argue from the possibility of the EPR experiment to the conclusion that there must be such a theory.

The sting turns on the predictions that quantum theory makes about the correlations between the results of the various possible measurements on the two particles of certain EPR systems. It was the significance of these correlations that was first noticed by Bell in the mid-1960s. Bell considered a variant of the original EPR case (a version originally described by Bohm, (1951), pp. 614-19). Fortunately for lay readers, we don’t need to know the details of Bohm’s case or Bell’s Theorem to appreciate its puzzling character. The essential features can be described in terms of an informal and much more commonplace analogue. As we shall see, very little mathematical thought is required to show that if analogous correlations were to arise in familiar regions of the world, they would strike us as very odd indeed.

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8It is important to appreciate that this does not show that Einstein was wrong: it simply saves his opponents from what would otherwise be a very serious objection. A common misconception is that Bell’s argument excludes hidden variable (HV) theories tout court. It does not. Even leaving aside the loophole discussed in the present paper, Bell’s result counts only against local HV views, leaving open the possibility of non-local HV theory—while non-locality itself can hardly be held to be a decisive failing in HV views if other views need it as well, as Bell’s result suggests that they do.

9I have adapted the following account from those given in several lucid and entertaining papers by the physicist N. David Mermin—see particularly his (1985) and (1981).
By modern standards the criminal code of Ypiaria\(^{10}\) allowed its police force excessive powers of arrest and interrogation. Random detention and questioning were accepted weapons in the fight against serious crime. This is not to say that the police had an entirely free hand, however. On the contrary, there were strict constraints on the questions the police could address to anyone detained in this way. One question only could be asked, to be chosen at random from a list of three: (1) Are you a murderer? (2) Are you a thief? (3) Have you committed adultery? Detainees who answered “yes” to the chosen question were punished accordingly, while those who answered “no” were immediately released. (Lying seems to have been frowned on, but no doubt was not unknown.)

To ensure that these guidelines were strictly adhered to, records were required to be kept of every such interrogation. Some of these records have survived, and therein lies our present concern. The records came to be analysed by the psychologist Alexander Graham Doppelgänger, known for his work on twins and co-operative behaviour. Doppelgänger realised that amongst the many millions of cases in the surviving records there were likely to be some in which the Ypiarian police had interrogated both members of a pair of twins. He was interested in whether in such cases any correlation could be observed between the answers given by each twin.

As we now know, Doppelgänger’s interest was richly rewarded. He uncovered the two striking and seemingly incompatible correlations now known collectively as Doppelgänger’s Twin Paradox. He found that

**SAME** When each member of a pair of twins was asked the same question, both always gave the same answer;

and that

**DIFF** When each member of a pair of twins was asked a different question, they gave the same answer on close to 25% of such occasions.

It may not be immediately apparent that these results are in any way incompatible. But Doppelgänger reasoned as follows. SAME means that whatever it is that disposes Ypiarians to answer Y or N to each of the three possible questions 1, 2 and 3, it is a disposition that twins always have in common. For example, if “YYN” signifies the property of being disposed to answer Y to questions 1 and 2 and N to question 3, then correlation

SAME implies that if one twin is YYN then so is his or her sibling. Similarly for the seven other possible such states: in all, for the eight possible permutations of two possible answers to three possible questions. (The possibilities are the two “homogeneous” states YYY and NNN, and the six “inhomogeneous” states YYN, YNY, NYY, YNN, NYN and NNY.)

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\(^{10}\)Pronounced, of course, “E-P-Aria”.
Turning now to DIFF, Doppelgängler saw that there were six ways to ask a different question to each of a pair of twins: the possibilities we may represent by $Q_{12}$, $Q_{21}$, $Q_{13}$, $Q_{31}$, $Q_{23}$ and $Q_{32}$ (“$Q_{ij}$” thus signifies that the first twin is asked question $i$ and the second question $j$). How many of these possibilities would produce the same answer from both twins? Clearly it depends on the twins’ shared dispositions. If both twins are YYN, for example, then $Q_{12}$ and $Q_{21}$ will produce the same response (in this case, Y) and the other four possibilities will produce different responses. So if YYN twins were questioned at random, we should expect the same response from each in about $1/3$ of all cases. Similarly for YNY twins, YNN twins, or for any of the other inhomogeneous states. And for homogeneous states, of course, all six possible question pairs produce the same result: YYY twins will always answer Y and NNN twins will always answer N.

Hence, Doppelgänger realised, we should expect a certain minimum correlation in these different question cases. We cannot tell how many pairs of Ypiarian twins were in each of the eight possible states, but we can say that whatever their distribution, confessions should correlate with confessions and denials with denials in at least $1/3$ of the different question interrogations. For the figure should be $1/3$ if all twins are in inhomogeneous states, and higher if some are in homogeneous states. And yet, as DIFF describes, the records show a much lower figure.

Doppelgänger initially suspected that this difference might be a mere statistical fluctuation. As newly examined cases continued to confirm the same pattern, however, he realised that the chances of such a variation were infinitesimal. His next thought was therefore that the Ypiarian twins must generally have known what question the other was being asked, and determined their own answer partly on this basis. He saw that it would be easy to explain DIFF if the nature of one’s twin’s question could influence one’s own answer. Indeed, it would be easy to make a total anti-correlation in the different question cases be compatible with SAME—with total correlation in the same question cases.

Doppelgänger investigated this possibility with some care. He found however that twins were always interrogated separately and in isolation. As required, their chosen questions were selected at random, and only after they had been separated from one another. There therefore seemed no way in which twins could conspire to produce the results described in SAME and DIFF. Moreover, there seemed a compelling physical reason to discount the view that the question asked of one twin might influence the answers given by another. This was that the separation of such interrogations was usually space-like in the sense of special relativity; in other words, neither interrogation occurred in either the past or the future light-cone of the other. (It is not that the Ypiarian police force was given to space travel, but that light travelled more slowly in those days. The speed of a modern carrier pigeon is the best current estimate.) Hence according to the principle of the relativity of simultaneity, there was no determinate sense in which one interrogation took place before the other. How then could it be a
determinate matter whether interrogation 1 influenced interrogation 2, or vice versa?\

How are we to explain Doppelgänger’s remarkable observations? Doppelgänger himself seems reluctantly to have favoured the telepathic hypothesis—the view that despite the lack of any evident mechanism, and despite the seeming incompatibility with the conceptual framework of special relativity, Ypiarian twins were capable of being “instantaneously” influenced by their sibling’s distant experiences. Doppelgänger was well aware that there is an hypothesis that explains same and different without conflicting with special relativity. It is that the twins possess not telepathy but precognition, and thus know in advance what questions they are to be asked. However, he felt that this interpretation would force us to the conclusion that the Ypiarian police interrogators were mere automatons, not genuinely free to choose what questions to ask their prisoners. Other commentators have dismissed the interpretation on different grounds, claiming that it would give rise to causal paradoxes.

In my view neither of these objections is philosophically well-founded. The relativity-friendly alternative that Doppelgänger rejects is certainly counterintuitive, but it is not absurd. Given the nature of the case, any workable explanation will be initially counterintuitive. What matters is whether that intuition withstands rigorous scrutiny, and of course how much gain we get for any remaining intuitive pain. Doppelgänger himself was well aware of the gains that would flow from the interpretation in question (especially that it saves special relativity), but thought the pain too high. I want to show that he was mistaken.\footnote{There are a number of concerns that might arise here, but the one that Doppelgänger seems to have found most pressing is this: if we allow space-like influences of this kind, then if it is not to be an arbitrary matter at what time a given influence “arrives”, certain inertial frames must be physically distinguished from others, in violation of the spirit of special relativity.}

3. Advanced action: how it explains the Twin Paradox.

Very little is known about the factors which must have governed an Ypiarian’s answers to the three questions permitted under Ypiarian law. The surviving records tell us what was said but not in general why it was said. The psychological variables are hidden from us, and must be inferred, if at all, from the behavioural data to which we have access. However, the puzzling character of the data is easily explained if we allow that the relevant variables display what physicists call advanced action: the property that the underlying psychological variables may depend on the future experiences of the agents concerned. Specifically, what is required is that pairs of twins who are in fact going to be\

\footnote{In saying this I am claiming no special insight or competence with respect to Ypiarian psychology, of course. My suggestion is simply that the specialists in that field have been led astray by considerations which fall more within philosophy than within their own discipline.}
asked different questions are therefore more likely to adopt an inhomogeneous state that yields different answers to those questions. Hidden variables are thus dependent on the fate of the agents concerned, as well on their history.

Consider for example a pair of twins $T_{dum}$ and $T_{dee}$ whose fate is in fact to be asked questions 2 and 3 respectively. Doppelgänger’s correlation diff suggests that this fate has the effect of making it less likely that $T_{dum}$ and $T_{dee}$ will be in the states YYY, YNN, NYY and NNN that yield the same answer to questions 2 and 3; and correspondingly more likely that $T_{dum}$ and $T_{dee}$ will be in one of the states YYN, YNY, NYN and NNY that yield different answers to these questions.

Unlike Doppelgänger’s instantaneous action-at-a-distance, this advanced action proposal does not conflict with special relativity. This is because the point at which twins become coupled—whether their conception, their birth, or some later meeting—lies well within the light-cones of both their later interrogations. The effect is not instantaneous and not at a space-like distance. And it needs no mysterious carrier. It has the twins themselves, who bear the marks of their future as they bear the marks of their past.

Why has this interpretation not appealed to Doppelgänger and other specialists in this field? As noted earlier, it is because they think that there is something absurd or contradictory in the idea that present events might exhibit this kind of correlation with future events. The objection resolves into two main strands. The first, which seems to have been the more influential in Doppelgänger’s own case, is the intuition that advanced action leads to fatalism—that it is incompatible with the ordinary supposition that the future events concerned are ones with respect to which we (or the Ypiarian interrogators) have independent present control and freedom of choice. We shall return to this strand of the objection in section 5.

The second strand of the objection is the claim that the correlations required for advanced action could be exploited to yield “causal paradoxes” of one kind or another. This claim depends on a venerable line of reasoning, essentially the so-called “bilking argument”. But what are these paradoxes, and need they arise in the Ypiarian case? I think we can show that they might not.

4. Causal paradox?

The supposed paradox is familiar from countless science fiction stories. The hero travels into her own past and takes steps to ensure that she will not exist at the time she left—she kills her young self, introduces her mother-to-be to contraception, persuades her Author to take up accounting, or something of the kind. The results are contradictory: the story tells us that something is both true and not true. It is like being told that it was the best of times and the worst of times, except that we are offered an account of how this contradictory state of affairs came to pass. This has the literary advantage of separating the beginning
of the story from the end, and the logical advantage of allowing us to conclude that something in the offered account is false. In physical rather than literary mode we can thus argue against the possibility of time travel: if there were time travel we could design an experiment with contradictory results; \textit{ergo}, there is no time travel. And as for time travel, so for backward causation. Causing one’s young self to have been pushed under a bus is just as suicidal as travelling in time to do the deed oneself.

In summary, then, the view that backward causation leads to causal paradoxes rests on the claim that if there were such causation, it could be exploited to allow retroactive suicide and other less dramatic but equally absurd physical results. But is this true of the kind of backward influence I claimed to find in the Ypiarian case? Could YES, the Ypiarian Euthanasia Society, exploit it in the interests of painless deaths for its aging members?

Unfortunately not, I think. For what is the earlier effect—the claimed result of the later fact that a pair of twins $T_{dum}$ and $T_{dee}$ are asked questions 2 and 3, say? It is that the state in which $T_{dum}$ and $T_{dee}$ separate is less likely to be one of those (YYY, YNN, NYY or NNN) in which questions 2 and 3 give the same response. For simplicity let us ignore the probability, making the effect correspondingly stronger. Assume, in other words, that such a fate guarantees that $T_{dum}$ and $T_{dee}$ will not be in one of these states. Retroactive suicide then requires that this effect be wired to produce the desired result—that a device be constructed that kills the intended victim if $T_{dum}$ and $T_{dee}$ do not have one of the excluded states. (This machine might be too generous, if other future possibilities do not prevent the past state of affairs that triggers it; but this won’t worry the members of YES, who will not be concerned that they might already have killed themselves—accidentally, as it were.) The trigger thus needs to detect the relevant states of $T_{dum}$ and $T_{dee}$, \textit{before the occurrence of the claimed future influence on these states}—before $T_{dum}$ and $T_{dee}$ are next interrogated by the Ypiarian police. But why suppose it is physically possible to construct such a detector? We know these states can be detected by the process of interrogation—\textit{in effect they are dispositions to respond to such interrogation in a certain way}—but this is not to say that they are ever revealed in any other way.

We thus have the prospect of an answer to the bilking objection. The thought

\footnote{I am simplifying here, of course. For one thing it is clear that even given the hypothesis of time travel, we are never actually justified in expecting the experiment to yield contradictory results, for logic alone rules that out. A number of authors have made this the basis of a defence of the possibility of time travel against the bilking argument. (See Horwich (1975), Lewis (1976) and Thom (1974), for example.) This issue is not directly relevant to our present concerns, which exploit a much larger loophole in the bilking argument. In passing, however, let me record my view—similar to that of Horwich (1987), ch. 7—that the bilking argument survives the former challenge. Roughly speaking, it shows us that hypothesis of time travel can be made to imply propositions of arbitrarily low probability. This is not a classical \textit{reductio}, but it is as close as science ever gets.}

\footnote{“YES for the right to say NO!”, as their slogan goes.}
experiments involved rest on an assumption that might simply be false. The supposedly paradoxical experiment might be physically impossible. This is a familiar kind of response to such arguments in science. Consider for example the old argument that space must be infinite, since if it were finite one could journey to the edge and extend one’s arm. One response to this is to point out that even if space were finite the required journey might be physically impossible, because a finite space need have no edges.

It is perhaps impossible at this distance to adjudicate on the Ypiarian case. Doppelgänger’s work notwithstanding, we know too little of Ypiarian psychology to be able to say whether the relevant states would have been detectable before interrogation. It is enough that because the bilking argument depends on this assumption, the backward causation proposal remains a live option.

5. The fatalist objection.

Now to Doppelgänger’s own main concern about the advanced action interpretation, namely that it seems to deny free will. If the Ypiarian interrogators’ choices of questions are correlated with the earlier psychological states of the twins concerned, then surely their apparent freedom of choice is illusory. For when they come to “decide” what questions to ask their “choice” is already fixed—already “written” in the mental states of their interviewees. This is the fatalist objection to advanced action.

The first thing to note about the fatalist objection is that it tends to slide back into a version of the bilking argument. If we think of “already determined” as implying “accessible”, then we seem to have the basis of a paradox-generating thought experiment. Since we have already discussed the bilking argument, let us assume that “already determined” does not imply “accessible”. What then remains of the fatalist point?

The strategic difficulty now is to set aside this objection to advanced action without calling on a philosophical dissertation on the topic of free will. Two points seem to be in order. The first is that even if the argument were sound, it would not show that advanced action is physically impossible. Rather it would show that advanced action is physically incompatible with the existence of free will. In the interests of theoretical simplicity the appropriate conclusion might then be that there is no free will. Free will might then seem another piece of conceptual anthropocentrism, incompatible (as it turns out) with our best theories of the physical world. So the fatalist objection is strictly weaker than the causal paradox argument. If successful the latter shows that advanced action is physically impossible; the former, at best, merely that it is incompatible with free will.

15 The fact that the bilking argument depends on an assumption of this kind was pointed out by Michael Dummett (1964). Later we shall see that quantum mechanics is tailor-made to exploit Dummett’s loophole.
The second thing to be said about the fatalist objection is that it has a much more familiar twin. This is the argument that if statements about our future actions are “already” either true or false (even if we can’t know which), then we are not free to decide one way or the other. There are differing views of this argument among philosophers. The majority opinion seems to be that it is fallacious, but some think that the argument does rule out free will, and others that free will is only saved by denying truth values to statements about the future. On the last point, physicists perhaps have more reason than most to grant determinate truth values to statements about the future. Contemporary physics is usually held to favour the four dimensional or “block universe” view of temporal metaphysics, whereas the thesis that future truth values are indeterminate is typically thought to require the rival “tensed” view of temporal reality.

If we accept that statements about the future have truth values then there are two possibilities. If the ordinary fatalist argument is sound, then there is no free will. But in this case the fatalist argument against advanced action is beside the point. If there is no free will anyway, then it is no objection to advanced action if it implies that there is none. If the ordinary argument is unsound, on the other hand, then so surely is the backward version. For the arguments are formally parallel. If the refutation of the forward version does not depend on what makes it the forward version—in effect, on the special status of future tensed statements—then it depends on what the two versions have in common. If one argument fails then so does the other.

Indeed, what it seems plausible to say in the future case is something like this: statements about the future do have truth values, and some of these statements concern events or states of affairs which do stand in a relation of constraint, or dependence, with respect to certain of our present actions. However, what gives direction to the relation—what makes it appropriate to say that it is our actions that “fix” the remote events, rather than vice versa—is that the actions concerned are our actions, or products of our free choices. The fatalist’s basic mistake is to fail to notice the degree to which our talk of (directed) dependency rides on the back of our conception of ourselves as free agents. Once noted, however, the point applies as much in reverse, in the special circumstances in which the bilking argument is blocked.

At any rate, the more basic point is that the fatalist argument usefully distinguishes the backward case only if two propositions hold: (a) the classical (future-directed) fatalist argument is valid, and thus sound if future tensed statements do have truth values; and (b) there is a significant difference between the past and the future, in that past tensed statements do have truth values, whereas future tensed statements do not. Proposition (a) is a rather unpopular position in a philosophical debate of great antiquity. Proposition (b) is perhaps a less uncommon position, but one that modern physicists seem to have more reason than most to reject. Taken together, as they need to be if the fatalist objection to the advanced action interpretation is not to collapse,
these propositions thus form an unhealthy foundation for an objection to an otherwise promising scientific theory.

6. Quantum mechanics and backward causation.

The point of the Ypiarian example lies, of course, in the fact that it exactly mirrors the puzzling behaviour of certain two-particle quantum-mechanical systems. Doppelgänger’s same is effectively the feature of EPR systems on which the original EPR argument relied. And diff is the additional feature whose conflict with same was noted by Bell in 1965. The case mirrors Bohm’s version of the EPR experiment. The pairs of twins correspond to pairs of spin-1/2 particles in the singlet state. The act of asking a twin one of three specified questions corresponds to the Stern-Gerlach determination of the spin of such a particle in one of three equi-spaced directions perpendicular to the line of flight. The answers Y and N correspond on one side to the results “spin up” and “spin down” and on the other side to the reverse. Thus a case in which both twins give the same answer corresponds to one in which spin measurements give opposite results. Correlations same and diff follow from the following consequence of quantum mechanics: when the orientation of the Stern-Gerlach measurements differ by an angle \(\alpha\) then the probability of spin measurements on each particle yielding opposite values is \(\cos^2(\alpha/2)\). This probability is 1 when \(\alpha = 0\) (same) and 1/4 when \(\alpha = \pm120°\) (diff).

These predictions have been confirmed in a series of increasingly sophisticated experiments. Thus if you thought the proper response to the Ypiaria story was that it was simply unrealistic, you should think again. Not only is the perplexing behaviour of Ypiarian twins theoretically and practically mirrored in quantum mechanics, but quantum mechanics actually tells us what sort of neurophysiology would make people behave like that. All we have to suppose is that the brains of Ypiarian twins contain the appropriate sort of correlated spin-1/2 particles (one particle in each twin), and that interrogation causes a spin determination, the result of which governs the answer given.

As in the Ypiarian case, it is easy to explain Bell’s results if we allow that particle states can be influenced by their fate as well as their history. One way to do it is to allow for a probabilistic “discoupling factor” which depends on the actual spin measurements to be performed on each particle and which influences the underlying spin properties of the particles concerned. We simply say that the production of such particle pairs is governed by the following constraint:

\[
\text{SET}\quad \text{In those directions G and H (if any) in which the spins are going to be measured, the probability that the particles have opposite spins is } \cos^2(\alpha/2), \quad \text{where } \alpha \text{ is the angle between G and H.}
\]

\[16\text{Most notably those of Alain Aspect et. al.—see Mermin (1985), pp. 45-6.}\]
Note that this condition refers to the fate of the particles concerned; it allows that their present properties are in part determined by the future conditions they are to encounter. Thus it explicitly violates Bell’s Independence Assumption. [17]

How does set cope with the kind of objections to advanced action that we dealt with in the Ypiarian case? We saw that the causal paradox objection rested on assumption that the claimed earlier effect could be detected in time to prevent the occurrence of its supposed later cause. What does this assumption amount to in the quantum mechanics case? Here the claimed earlier effect is the arrangement of spins in the directions G and H which are later to be measured. But what would it take to detect this arrangement in any particular case? It would take, clearly, a measurement of the spins of particles concerned in the directions G and H. However, such a measurement is precisely the kind of event which is being claimed to have this earlier effect. So there seems to be no way to set up the experiment whose contradictory results would constitute a causal paradox. By the time the earlier effect has been detected its later cause has already taken place. [18]

The advanced action explanation of Bell’s results thus lacks the major handicap with which it has usually been saddled. On the other side, it has the advantages we noted in the Ypiarian case. For one thing, it does not seem to call for any new field or bearer of the influence that one measurement exerts on another. If we think of the fate of a particle as a property of that particle—a property which has a bearing on the results of its interaction with its twin—then the particles themselves “convey” the relevant influence to its common effect at the point at which they separate. More importantly, by thus confining the retro-influence of future measurements to their past light-cones, the advanced action account avoids action at a distance, and hence the threat of conflict with special relativity.

The extent of the last advantage clearly depends on how much alternative explanations do conflict with special relativity. This has been a topic of considerable discussion in recent years. [19] It is widely agreed that the Bell correlations do not permit faster than light signalling, but the issue of “causal influence” is less straightforward. Whatever the nature of the influence, the concern seems in part to be that special relativity implies that any space-like influence will be

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[17] Set should be taken simply as an illustration of the general strategy, of course. Recall that we began with Bell’s own observation that if we are prepared to abandon the Independence Assumption, his results no longer stand in the way of a local hidden variable theory for quantum mechanics—a local realist theory, in Einstein’s sense. The issue of the best form for such a theory is a technical matter, beyond the scope of the present paper. The present argument is simply that in philosophical terms Bell’s loophole is much more attractive than it has usually been taken to be, and hence that the technical strategy it embodies has been unjustly neglected.

[18] In effect, quantum mechanics thus builds in exactly what we need to exploit the Dummettian loophole in the bilking argument.

[19] There is an up-to-date analysis in Butterfield (1994), and a survey of the field in Maudlin (1994), chs. 4-6.
a backward influence from the point of view of some inertial frame of reference. Backward influence has seemed problematic on the grounds we have already examined: “It introduces great problems, paradoxes of causality and so on.” (Bell again, in Davies and Brown 1986, p. 50) Now if this were the only problem with Bell’s preferred non-local influences, that fact would weaken our case for preferring backward to space-like influence; for it would mean that in rejecting the usual argument against backward causation we would also be removing the main obstacle to Bell’s own faster-than-light interpretation of the phenomena.

There is another problem with Bell’s view, however, namely the concern we noted in the Yparian case: a space-like influence seems to distinguish one inertial frame of reference from all the rest—it picks out the unique frame according to which the influence concerned is instantaneous. This appears to contradict the accepted interpretation of special relativity, namely that all inertial frames are physically equivalent. It was this consequence to which Bell was referring in the passages I quoted at the beginning of the paper. As he puts it elsewhere, the view commits us to saying that “there are influences going faster than light, even if we cannot control them for practical telegraphy. Einstein local causality fails, and we must live with this.” (1987, p. 110) As I have emphasised, the advanced action interpretation requires no such reconstruction of special relativity. So unless there is more to be held against this approach than the charges of fatalism and causal paradox, it would appear to offer a rather promising explanation of the Bell correlations.

I have concentrated on the EPR cases because it is here that in virtue of the threatened conflict with special relativity the advantages of backward influence (or advanced action) are most apparent. Concerning quantum mechanics more generally, I think its appeal turns on its ability to revitalise that other aspect of Einstein’s world view, namely the conviction that quantum mechanics provides an incomplete description of the physical world. As I noted earlier, the extent to which Bell’s Theorem undermines this Einsteinian view is commonly exaggerated. The present loophole aside, Bell’s result simply undermines local versions of such a view—which, given that it appears to undermine locality generally, can hardly be counted a decisive objection to Einstein. All the same, the present loophole does seem to swing the argument strongly in favour of the Einstein view: given that orthodox quantum mechanics does not embody the required “backward influence”, only a model which takes the orthodox theory to be incomplete will be capable of doing so. Only some version of the Einstein view seems able to save locality in this way.

A revitalised Einsteinian view would have the attractions it always held for the interpretation of quantum mechanics. Its great virtue is that because it denies that the collapse of the wave function corresponds to a real change in the physical system concerned, it does not encounter the so-called “Measurement

20Far from being the man who proved Einstein wrong, Bell thus appears in this light to be the man who provided a new reason to think that Einstein was right.
Problem”, which is essentially the problem of providing a principled answer to the question as to exactly when such changes take place. The fact that the Measurement Problem is an artefact of a particular way of interpreting quantum mechanics has tended to be forgotten as the views of Einstein’s Copenhagen opponents have become the orthodoxy, but it was well appreciated in the early days of the theory. As Lockwood (1989, pp. 196-7) makes clear, the point of Schrödinger’s original use of his famous feline gedankenexperiment was precisely to distinguish these two ways of looking at quantum theory, and to point out that unlike the view of the theory that he himself shared with Einstein, that of their Copenhagen opponents would be saddled with the problem of the nature and timing of measurement.

Although it avoids the standard Measurement Problem, it might seem that the view I am suggesting—Einsteinian realism with advanced action—will face a measurement problem of its own. For if the claim is that earlier hidden variables are affected by later measurement settings, don’t we still need a principled account of what counts as a measurement? This is a good point, but the appropriate response seems not to be to try to distinguish measurements from physical interactions in general, but to note that it is a constraint on any satisfactory development of this strategy for quantum theory that the advanced effects it envisages be products of physical interactions in general, rather than products of some special class of “measurement” interactions.

This point is relevant to another charge that might be levelled against the suggested approach. It might be argued that the approach fails to respect the core thesis of Einstein’s realism, namely the principle that there is an objective world whose nature and reality are independent of human observers. If our present measurements affect the prior state of what we observe, then surely the external world is not independent in Einstein’s sense. Had we chosen to make a different measurement, the external world would have been different. Isn’t this very much like the observer-dependence that Einstein found objectionable in the Copenhagen view?

I think it is best to answer this charge indirectly. First of all, I think we may assume that Einstein would not have felt that his brand of realism was threatened by the observation that human activities affect the state of the external world in all sorts of ordinary ways. The existence of trains, planes and laser beams does not impugn realism. The processes that produce such things are simply physical processes, albeit physical processes of rather specialised kinds. Secondly, it seems fair to assume that backward causation is not in itself contrary to spirit of Einsteinian realism. On the contrary, a realist of Einstein’s empiricist inclinations might well think that the direction of causation is a matter to be discovered by physics. But then why should the existence of backward effects of human activities be any more problematic for realism than the existence

\[21\] To the extent that causation itself is regarded as a physically respectable notion, at any rate. Other views are possible, of course, but then the objection to backward causation will not be specifically that it threatens classical realism.
of their “forward” cousins? Provided we make it clear that in the first place the view is that certain physical interactions have earlier effects, and not that certain specifically human activities do so, the position does not seem to be one that an empiricist of Einstein’s realist persuasions should object to a priori. For what the view proposes, roughly speaking, is simply to extend to the case of the past a form of lack of independence that realists find unproblematic in the case of the future. The proposal might perhaps be objectionable for other reasons, but it does not conflict with realist intuitions of Einstein’s sort.

In summary, then, the advanced action approach promises the usual virtues of the “incompleteness” interpretation of quantum mechanics favoured by Schrödinger, Born, Einstein, Bohm and Bell himself. Unlike other versions of this view (and apparently all versions of the opposing orthodoxy), it also promises to save locality, and therefore to avoid the threatened conflict between quantum mechanics and special relativity. The restrictions that quantum mechanics places on measurement enable the approach to exploit a well-recognised loophole in the bilking argument—while interpreting the required failure of the Independence Assumption in terms of backward causation seems to sidestep Bell’s own concerns about free will.

7. Conceptual inertia and the puzzle of causal asymmetry.

Striking as it is, however, I have come to appreciate that the above argument has the following rather disappointing characteristic: it is almost completely unpersuasive. Even its most receptive audiences seem to find themselves in the grip of a kind of conceptual inertia—a phenomenon to which, as it stands, the argument simply makes no concessions. In effect, the argument assumes that the ordinary view that there is no backward causation is just another scientific hypothesis, amenable to revision on empirical grounds. But causation is a pre-scientific notion, deeply ingrained in folk usage and philosophically problematic. At the very least, therefore, an argument with such radical conclusions on the subject needs to be backed up with a kind of metaphysical user’s manual—a guide to some of the philosophical issues in the background, so that interested parties might have a better sense as to what they are being invited to endorse.

One function for such a guide might well be cognitive therapy. The unpopularity of the backward causation approach to the interpretation of quantum mechanics—a field not noted for metaphysical conservatism!—itself suggests that the intuitions that oppose it are very deeply ingrained. In order to give the approach a fair hearing, then, it seems appropriate to ask where these intuitions come from, and why they are so resistant to arguments of the above kind. As

Perhaps I’m being unduly pessimistic here, but try the following experiment: imagine that you find the steps in the argument individually convincing, so that you now accept that the advanced action interpretation has the advantages described above. Are you now disposed to believe that quantum mechanics shows that the world contains backward causation? I suspect not, for the kind of reasons outlined below.
in psychoanalysis, uncovering the aetiology of our aversions might be the first step to their successful treatment.

Whatever the motivation for the project, however, an obvious starting point is a reflection on the nature and origins of causal asymmetry in “classical” cases. One of the puzzling features of our intuitions concerning the temporal asymmetry of causation and physical dependency is that they seem to be quite independent of what we know of the temporal symmetry of the underlying physical processes concerned. This is especially striking in simple microphysical examples. Consider, for example, a photon emitted from an excited atom in some distant galaxy, and eventually absorbed in the reverse process on Earth (perhaps in a detector connected to a telescope). Suppose that the photon happens to pass through polarisers at both ends of its journey. By our intuitive standards, nothing could be more natural than the thought that while the state of the photon as it nears the Earth might depend on the setting of the distant polariser (perhaps million of years in its past), it doesn’t depend on the setting of the local polariser (perhaps only microseconds in its future). Yet if the physics is symmetric—if from the physical point of view it is simply a conventional matter which extremity of the photon’s journey we choose to regard as the beginning and which the end—then what could possibly explain this difference?

As this example illustrates, there is a prima facie tension between the striking temporal symmetry of contemporary physical theory and the prevailing intuition that causation is not only asymmetric but “unidirectional”—always oriented in the same temporal direction. True, this tension is commonly said to be defused by the recognition that causal direction is a physically contingent feature of the world—“fact-like” rather than “law-like”, as physicists often say. But given that this response usually associates causal direction with the thermodynamic asymmetry, itself normally taken to be statistical and thus macroscopic in origin, it is doubtful whether it provides much support for applying our ordinary causal intuitions to microphysics.\(^{23}\)

In my view the most plausible resolution of the apparent tension rests on the thesis that the asymmetry of causal dependency is anthropocentric in origin. Roughly, the suggestion is that we ourselves are asymmetric in time, and that this subjective asymmetry comes to be embedded in the way we talk about the world. To argue this way is not to deny that there are objective temporal asymmetries in the physical world. It is simply to point out that some of the apparently “external” asymmetries may be “internal” in origin.\(^{24}\) Thus the asymmetry we think we see in the photon case is explained as a shadow of a

\(^{23}\)I develop this objection in Price (1992).

\(^{24}\)The claim is not undermined by the requirement that the “internal” asymmetries concerned should themselves be explicable “externally”—i.e., in terms of objective physical asymmetries in the world—so long as the latter asymmetries are not those being held to be projections of our own internal asymmetry. A plausible hypothesis is that our own existence and temporal asymmetry is ultimately explicable in terms of the thermodynamic asymmetry of the universe in which we live. This explanation does not presuppose an objective causal asymmetry, however.
real asymmetry elsewhere, and no longer seems in conflict with the symmetry of the photon’s intrinsic physics.

In the present context, another advantage of this suggestion might seem to be that it promises to explain why the backward causation interpretation of Bell’s results meets with such resistance. If ordinary causal talk is a product of some very basic characteristics of the sort of creatures we are, small wonder that it is so deeply entrenched, and that we find it so difficult to revise. This argument needs to be handled with care, however, for if causal asymmetry is anthropocentric, how can there be an objective issue as to whether causation is “forward” or “backward”? The objective content of the backward causation strategy seems to have been lost.

We shall be able to turn this point to our advantage, however. The view that the asymmetry of dependency is anthropocentric will enable us to clarify the objective core of the advanced action proposal. The trick will be to distinguish between two kinds of correlational structures for the world. From the standard point of view one possible structure “looks like” it simply contains ordinary forward causation, while the other “looks like” it contains a mixture of forward and backward causation. The latter structure is the one we need to solve Bell’s riddle. Its objective content lies in its correlational structure, but the causal viewpoint provides a useful way to distinguish it from the classical alternative. All the same, it seems that Nature has played a practical joke at this point, hiding the narrow path to the advanced action interpretation between two much more clearly marked alternatives: on the one hand the path that accepts that our intuitive notion of directed causation is of fundamental physical significance; on the other the path that banishes causation from physics altogether. There is a middle way, but we shall need to tread carefully.

So the problem of the asymmetry of dependency—the puzzle exemplified by the photon case—promises an illuminating route to a deeper understanding both of what is at issue in the debate about backward causation in quantum mechanics, and of the place of our ordinary views about causation in our system of theoretical commitments as a whole. And that in turn promises to counter the conceptual inertia we noted at the beginning of the section. In so far as that inertia is rationally grounded, much of it seems to stem from uncertainty concerning the physical content of the advanced action interpretation; an uncertainty engendered by the philosophical complexities of the relationship between causation and physics. By clarifying the commitments of the interpretation in this way, we may thus hope to diminish the grounds for rational conservatism.

I suspect that the failure to notice this middle way is one reason why the backward causation approach has been unpopular among physicists. One commentator who seems to miss it is Bernard d’Espagnat. In discussions of the advanced action interpretation advocated by Costa de Beauverard (see note 40), d’Espagnat appears to move from an acknowledgment of the “apparently irreplaceable role of man-centred concepts in the very definition of the causality concept” to the view that there is little of any novelty or promise in the claim that quantum mechanics reveals backward causation. See his (1989a), pp. 229-31, and (1989b), pp. 144-5.
My treatment of these issues goes like this. The first task is to outline a case for a treatment of the asymmetry of dependency on the anthropocentric lines just indicated. The argument will be couched in terms of counterfactual conditionals, which seem to provide the most transparent route to the insights we are after. As we shall see, a natural objection to this approach is that in tying the asymmetry of dependency to a conventional feature of our use of counterfactuals, it fails to capture the intuitive objectivity of the asymmetry. Responding to this objection will lead us back to the issue as to whether the approach leaves room for backward causation, and hence to the main concerns of the paper. I shall argue that the approach leaves just the space that the advanced action interpretation requires, and show how it clarifies what is objectively at issue between this interpretation and its more conventional rivals. Finally, we’ll see that this clarification puts us in range of a powerful new argument for the interpretation, namely that it seems to respect a temporal symmetry in microphysics that the classical view is bound to deny.

8. Asymmetry conventionalised.

The intuition I appealed to above was that the state of our photon does not depend on the fact that it is going to pass through a polarising lens in the near future, but may depend on the fact that it passed through such a lens in the distant past. What makes this intuition puzzling is that it is temporally asymmetric, without there being any apparent basis for such an asymmetry in the physical phenomena themselves.

A useful approach to this puzzle is to do away with explicit talk of dependency, by couching the intuitive asymmetry in counterfactual terms. Intuitively, it seems true that

(1) If the distant polariser had been differently oriented the incoming photon might now be in a different state (or might not have arrived here at all);

and yet false that

(2) If the local polariser had been differently oriented, the state of the incoming photon might have been different.

Granted that this contrast seems to capture the intuitive asymmetry, a tempting suggestion is that the asymmetry doesn’t really have anything to do with the physical entities themselves, but is buried in the content of counterfactual claims. After all, a popular account of the semantics of counterfactuals goes something like this. When we assess a counterfactual of the form “If X had happened at $t_1$ then Y would have happened at $t_2$”, we consider the consequences of a hypothetical alteration in the course of events. We “hold fixed” the course of events prior to $t_1$, assume that X occurs at that time, and consider the course of events that follows. Roughly speaking, we take the conditional to
be true if \( Y \) at \( t_2 \) is a consequence of the joint assumption of the actual history prior to \( t_1 \) and the occurrence of \( X \) at \( t_1 \).

According to this account, (1) says that if we hold fixed the history of the photon before it reaches the distant polariser, but assume that polariser to be differently oriented, we may derive different consequences for the state of the photon before it reaches the Earth (i.e., in the region between the two polarisers). Whereas (2) says that if we hold fixed the history of the photon before it reaches the local polariser, and assume that polariser to be oriented differently, we may derive different consequences for the state of the photon before it reaches the local polariser. The latter claim is clearly false, but for a rather trivial reason: the state of the photon doesn’t change under the assumed circumstances, because the assumption includes the supposition that it doesn’t.

The standard semantics for counterfactuals thus dissolves the puzzle of the photon case. Why doesn’t the present affect the past? Because to say that the present affected the past would just be to say that if the present had been different the past would have been different. And that in turn is just to say that if we suppose the present to be different, while the past remains the same, it will follow that the past is different. This is untrue, of course, but simply on logical grounds. No physical asymmetry is required to explain it.

But is this the right way of dissolving the tension? An obvious objection is that it makes our ability to affect the future but not the past a conventional or terminological matter. After all, couldn’t we have adopted the opposite convention, assessing counterfactuals by holding the future fixed—in which case wouldn’t we now be saying that present events depend on the future but not the past? And if there is this alternative way of doing things, how could one way be right and other way wrong? How could it be objectively the case, as it seems to be, that we can affect the future but not the past?

This objection might have a second aspect to it, closely related to our present concerns: we might feel that even if the past doesn’t depend on the future, it isn’t logically impossible that it should do so, in the way that this diagnosis would suggest. The suggested account of counterfactuals thus seems in one sense too weak, in failing to give due credit to a genuine difference between the past and the future; and in another sense too strong, in ruling out backward dependency by fiat.

In the next section I shall sketch what seems to me to be an adequate response to this objection, and try to show how it illuminates our main concern. The latter aspect of the objection is the more directly relevant of the two, of course, but the former is the more crucial to the credentials of the anthropocentric approach to asymmetry as a whole, and needs to be tackled first.

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26 See Jackson (1977), for example.
27 (2) isn’t really the temporal image of (1), in other words, and so the difference in their truth values doesn’t constitute a genuine temporal asymmetry.
28 A thorough response to the objection would involve a critique of alternative accounts of the asymmetry of dependency. I shall not attempt this here, but see my (1992) and (1993).
9. Convention objectified.

The objection is that the conventionalist account would make the asymmetry of dependency less objective than it actually seems to be—a matter of choice, in effect. The appropriate response, I think, is to draw attention to the constraints on this “choice” imposed by the circumstances in which we find ourselves, and over which we have no control. Because these constraints are so familiar we fail to notice them, and mistake the asymmetry they impose for an objective feature of the world. The moral is that things may seem more objective than they actually are, when the source of the subjectivity is not an obvious one.

The main constraint turns on the fact that counterfactuals are used in deliberation, and that deliberation is a temporally asymmetric process. Considered as structures in spacetime, agents (or “deliberators”) are asymmetric, and thus orientable along their temporal axis. The crucial point is that this orientation is not something an agent is able to choose or change. From an agent’s point of view it is simply one of the “givens”, one of the external constraints within which she or he operates.

Thus although our temporal orientation is probably a contingent matter—there might be agents with the opposite temporal orientation elsewhere in the universe—it is not something that we can change. Given what we do with counterfactuals in deliberation (more on this in a moment), we thus have no option but to assess them the way we do—that is, to hold the past rather than the future fixed. It is objectively true that from our perspective, we can’t affect our past. Unable to adopt any other perspective, however, and failing to notice the relevance and contingency of our temporal orientation, we fail to see that what we have here is a relational truth, a truth about how things are from a perspective, rather than absolute truth about the world. The account thus provides a kind of quasi-objectivity. It explains why we think of the asymmetry of dependency as an objective matter.

The account relies on the claim that agents are asymmetric and thus orientable in time. This doesn’t seem particularly contentious, but it would be useful to have a better understanding as to what this asymmetry involves. I think there are two ways to approach the issue. One would seek to characterise the asymmetry in terms of a formal model of deliberation. Roughly speaking, the goal would be to map the structure of an ideal deliberative process—to map it from an atemporal perspective, laying out the steps en bloc—and hence to be able to point to an intrinsic asymmetry along the temporal axis. This seems a plausible project, involving little more than transcribing standard dynamic models of deliberation into an atemporal key.

The other approach would be a phenomenological one, going something like this. From the inside, as it were, we perceive a difference between the inputs and the outputs of deliberation—between “incoming information”, which appears as “fixed”, or “given”, and “outgoing behaviour”, which appears as “open”, or subject to our control. The contrast is a subjective one, a feature of what it
feels like to be an agent, so that such difference would not be apparent from a genuinely external perspective. An atemporal God would just see a pattern of correlations in both temporal directions between the deliberator’s internal states and various environmental conditions (and wouldn’t regard the temporal ordering implied by the terms “input” and “output” as having any objective significance, of course). \[29\]

Either way, where do counterfactuals fit into the picture? We need to think about the role of counterfactuals in deliberation. An agent normally has the choice of a number of options, and bases her choice not on the desirability of the immediate options themselves, but on that of what might be expected to follow from them. Thus a typical deliberative move is to take what is “given” or “fixed”—or rather, in practice, what is known of what is taken to be fixed—and then to add hypothetically one of the available options, and consider what follows, in accordance with known general principles or laws. The temporal orientation of this pattern of reasoning follows that of the agent’s perspective. Broadly speaking, what we hold fixed when assessing counterfactuals according to the standard semantics is what presents itself to us as fixed from our perspective as agents. So long as counterfactuals are to maintain their association with deliberation, \[30\] in other words, our choice of the “hold the past fixed” convention is governed by the contingent but nevertheless unchangeable fact of our orientation as agents. We have no choice in the matter.

This account explains the apparent objectivity of the asymmetry of dependency, and thus meets the charge that the conventionalist strategy makes the asymmetry too weak. However, the objection was that the strategy is also too strong, in making it analytic and hence a priori that we cannot affect the past. We now need to show that the conventionalist approach leaves a loophole for backward causation—in other words, that this anthropocentric account to the asymmetry of dependency does not backfire on the main project of the paper. \[31\]

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29 This phenomenological account will appeal more than the formal one to philosophers who seek to ground folk concepts in folk experience. Do we need to adjudicate between the two? I don’t think so. It seems reasonable to expect that they will turn out to be complimentary. In effect, the formal approach will simply be describing the internal structure of the pattern of correlations on which the phenomenological approach depends.

30 There is no necessity in this, of course. We could, and in practice certainly do, use counterfactuals for other purposes. The claim is simply that in those contexts in which the symmetry of dependency seems vivid to us—contexts such as that of (1) and (2) above—the use is one which depends on this connection with deliberation.

31 Note that what we are interested in showing is that it is an empirical possibility that the world might contain what we would describe as backward causation; not merely that there might be differently-oriented creatures who would see it as containing what we would have to describe—to the extent that we could describe it—as backward causation. The issue is whether the conventionalist proposal make sense of the idea that even from our own perspective it is a posteriori that we can’t affect the past.
10. Backward dependency legitimised.

The crucial step is to appreciate that although it is *a priori* that we can’t affect what we know about at the time of deliberation, it is *a posteriori* that what we can get as input to deliberation is all and only what lies in our past. It is an interesting question why we should assume that this is the case. Even if experience teaches us that what we know about via memory and the senses always lies in the past, we would be affirming the consequent to conclude that anything that lies in the past is something that might in principle be known about, and hence something inaccessible to deliberation. In fact, it seems that the relationship between temporal location and epistemological accessibility is not only contingent (in both directions), but rather under determined by our actual experience. For all that our limited experience tells us, there might actually be some of the past to which we do not have access, and perhaps some of the future to which we do. The epistemological boundaries seem to be an empirical matter, therefore, to an extent that ordinary practice tends to overlook.

Here the point connects with our earlier discussion. We noted in section 4 that as Dummett (1964) points out, that it is possible to avoid the bilking argument so long as one confines oneself to the claim that one can affect bits of the past which are epistemologically inaccessible at the time that one acts. To make the example concrete, suppose it were suggested that the present state \( \phi \) of our incoming photon depended on the setting of the local polariser in its future, as well as on that of the distant polariser in its past. In this case the bilking argument would require that we measure \( \phi \) before the photon arrives, and thereby set the future polariser to conflict with the claimed correlation. So if the only way to measure \( \phi \) is to pass the photon through a polariser, and the claim in question is simply that the value of \( \phi \) depends on the orientation of the next polariser it encounters, bilking becomes impossible. Interposing another measurement would mean that the next measurement is not the one it would have been otherwise, so that the conditions of the claimed dependency would no longer obtain. According to the claim under test, such a measurement cannot be expected to reveal the value that \( \phi \) would have had if the measurement not been made.

By slipping into talk of counterfactuals and backward dependency here, I have tried to illustrate that this admission of limited retro-dependency is not as alien as might be imagined. It seems in particular that our use of counterfactuals is already somewhat more flexible than the model we have been using suggests—already sufficiently flexible to handle the kind of cases that Dummett’s loophole admits, in fact. What we seem to do in such cases is just what Dummett would have us do, in effect: we assess counterfactuals not by holding fixed everything prior to the time of the antecedent condition, but by holding fixed what we have access to at that time (without disturbing the background conditions of the claimed correlation).
This shows how the conventionalist can make sense of the possibility of backward dependency (and thus meet the second part of the objectivist’s challenge). Note that this response does not require that the ordinary use of counterfactuals is already unambiguously committed to this possibility, in the sense that it is already configured to take advantage of the Dummettian loophole. If that were so the assumption that the past does not depend on the future would surely be less deeply ingrained than it is in scientific theorising. It seems to me more accurate to say that there is a systematic indeterminacy in our ordinary notions of causal and counterfactual dependency. Ordinary usage does not clearly distinguish two possible conventions for assessing counterfactuals: a mode under which the entire past is held fixed, and a mode under which only the accessible past is held fixed. If we follow the former convention then it is analytic that the state of the incoming photon does not “depend” on the local polariser setting; whereas if we follow the latter convention it may do so. But this difference reflects an issue about how we should use the terms involved, rather than a disagreement about the objective facts of the matter.

The nice thing about this point is that it suggests a natural way of characterising the objective core of the advanced action interpretation. For it is clear that advocates of the two conventions for counterfactuals might agree on the relevant categorical facts. In the photon case, for example, they might agree that there is a one-to-one correlation between some feature of the state of the incoming photon and the setting of the later polariser. The difference is simply that the second convention (“hold the whole past fixed”) precludes us from interpreting this correlation in terms of backward influence.

Thus by separating the issue of the correlational structure of the world from that of the appropriate convention for counterfactuals, we seem to be able to insulate the empirical question we are interested in—a question concerning the structure of the microworld—from the heat of folk intuitions about what might depend on what. Faced with an opponent who claims to find backward dependency incoherent, we can simply concede counterfactual practice, and fall back to the categorical issue.

The point of this tactical move is to enable us to keep our eye on the issue that really matters for the interpretation of quantum mechanics, and it doesn’t commit us to being even-handed on the issue as to which choice of convention for counterfactuals would be the more appropriate in a world with correlations of the imagined kind. It seems to me that there would good reasons for preferring the weaker convention (“hold fixed the accessible past”), which become evident if we consider what the stronger convention would have us say about the imagined case. To simplify as much as possible, suppose that there is agreed to be a strict correlation between a particular polariser setting S and a particular earlier state $\phi_s$ of the incoming photon. If counterfactuals are assessed accord-

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32Strictly speaking what they will agree on is that this correlation holds in the class of actual cases of this kind. Modal generalisations might prove contentious.
ing to the stronger convention, it cannot be the case that both the following counterfactuals are true (for if we hold fixed events before S, then one consequent or other is bound to be false, even under the counterfactual supposition in question).

(3) If we were to bring about S, this would ensure that $\phi_s$

(4) If we were to bring about not-S, this would ensure that not-$\phi_s$.

Suppose for the sake of argument that the incoming photon is not in state $\phi_s$, so that it is (3) that has a false consequent (under the assumption that the past is held fixed). The two possibilities seem to be to regard (3) as false or to regard it as somehow meaningless, or otherwise inappropriate. To go the first way is to say that the agreed correlation between S and $\phi_s$ does not support counterfactuals. To go the second way seems to be to say that means-end reasoning breaks down here—that it doesn’t make sense to suppose we might do S. Neither course seems particularly satisfactory. We are supposing that all parties acknowledge that as a matter of fact the correlation does always obtain between S and $\phi_s$, including on whatever future occasions there might happen to be on which we bring about S. Outcomes of actual actions thus assured, it is hard to see how the refusal to acknowledge the corresponding counterfactuals could seem anything but wilful—so long, at any rate, as we claim the ability to bring about S at will. Denying free will seems to be an alternative, but in this case it should be noted that the phenomenology isn’t going to be any different. So there is nothing to stop us from going through the motions of deliberating, as it were. Within this scheme of quasi-deliberation we’ll encounter quasi-counterfactuals, and the question as to how these should be assessed will arise again. Hold fixed the past, and the same difficulties arise all over again. Hold fixed merely what is accessible, on the other hand, and it will be difficult to see why this course was not chosen from the beginning.

Thus I think that if we were to find ourselves in a world in which the notions of the past and the epistemologically accessible came apart in this way—a world in which it thus became important to resolve the ambiguity of current counterfactual usage—a resolution in favour holding fixed merely what is accessible would be the more satisfactory. For present purposes, however, the important point is that this issue about how we should use counterfactuals is quite independent of the empirical issue as to whether the world has the correlational structure that would require us to make the choice.

In sum, the proposal that the asymmetry of dependency rests on a conventional asymmetry in the content of counterfactual claims leaves open the possibility of exceptional cases, in which the past would indeed be properly said to depend on the future. But it leaves open this possibility not in the direct sense that current usage unambiguously admits it, but in the sense that in conceivable physical circumstances the most natural way to clarify and disambiguate current usage would be such as to recognise such backward influence. Finally,
it should be emphasised that this sort of backward causation will not be the time-reverse of ordinary forward causation, since our own temporal orientation and perspective remains fixed.

Arguing for a bare possibility is one thing. Arguing that the actual world is like this is quite another, of course, but it is worth noting that any such argument seems bound to be indirect. The kind of backward influence concerned is not likely to be directly observable case by case, for the simple reason that if it were, the bilking argument would again gain a foothold. So the case for such a model of the world will have to rely on non-observational considerations—considerations of simplicity, elegance and symmetry, for example. This takes us neatly back to our starting point. The argument for the advanced action interpretation rested on a number of theoretical advantages of this kind—especially its ability to avoid non-locality and hence conflict with special relativity, but also the promise of the advantages of “incompleteness” interpretations in general. It is useful to be reminded that we shouldn’t expect evidence of a more direct kind: we shouldn’t expect to “see” backward influence in action, as it were.

11. The symmetry argument for advanced action.

But is the indirect case as strong as it might be? A tempting thought is that there might be a symmetry argument in favour of the advanced action view. If classical views of microphysics turned out to embody a temporal asymmetry which could be removed by reinterpreting the theories concerned in such a way as to allow backward dependency, then we would seem to have a strong argument in favour of such a reinterpretation.\[33\]

It is important to note that the simple asymmetry of dependency exemplified by the photon case is not problematic in this way, being explicable in terms of the conventional asymmetry of counterfactuals. Recall that the crucial point was that the counterfactuals (1) and (2) are not genuinely the temporal inverse of one another, so that their difference in truth value does not require a genuine temporal asymmetry. What would be problematic would be the claim that the categorical constituents of the world were asymmetric on the micro scale. It has sometimes been noted that this seems to be true of the standard interpretation of quantum mechanics, according to which the wave function is localised after but not before a measurement interaction.\[34\] So much the worse for the standard interpretation, in my view, but that’s an argument for another time. In the present context the interesting thing is that any hidden variable theory which fails to allow advanced action seems likely to violate this symmetry requirement.

To see why this is so, let us return to the photon case. The easiest way to think about the difference between the advanced action interpretation and its

\[33\] Why? Simply because it would eliminate an otherwise mysterious breach of symmetry. Reasoning of this kind is common in physics.

\[34\] See Penrose (1989), pp. 354-6, for example.
orthodox rivals is in terms of counterfactuals assessed according to the “hold fixed the accessible past” convention, which permit retro-dependency. (There is no logical impropriety in discussing the case in these terms, so long as we keep in mind that the objective content of the issue concerns patterns of correlation.) The orthodox view is that the state $\phi$ of the photon between the polarisers does not depend on the setting of the future polariser. If we assume that what is accessible is the state of the photon in the region prior to the past polariser, this independence assumption amounts to the following:

(5) With the history prior to the past polariser held fixed, changes in the setting of the future polariser do not imply changes in the value of $\phi$ in the region between the polarisers.

In order to determine whether this view involves a temporal asymmetry, we need to ask whether it also endorses the temporal inverse of this assumption, which is:

(6) With the course of events after the photon passes the future polariser held fixed, changes in the setting of the past polariser do not imply changes in the value of $\phi$ in the region between the polarisers.

There is little intuitive appeal in this latter proposition, however. The easiest way to see this is to imagine more familiar cases in which we talk about alternative histories. For example, suppose that we have an artefact, known to be a year old, which could have been manufactured by one of two processes. Given its present condition, does our view about its condition say six months ago depend on our view about its origins? Obviously it might well do so. In the one case, for example, the distinctive patina on the surface of the object might have been a product of the manufacturing process itself; in the other case it might have been acquired gradually as the object aged. So there is no reason to expect the condition of the object in the intervening period to be independent of what happened to it in the past.

In endorsing (5) but not (6), then, the orthodox view seems to be committed to a genuine asymmetry—the sort of asymmetry which is not needed to account for the contrast between (1) and (2). The advanced action view avoids this asymmetry, by rejecting (5) as well as (6). This appears to be a powerful additional argument in favour of the advanced action view. How could such an argument have been overlooked? The answer, I take it, is that it has not been noticed that the orthodox assumption involves anything more than the ordinary asymmetry of physical dependency, exemplified by the contrast between (1) and (2). Since the latter contrast is rightly assumed to involve no violation of physical symmetry principles, it has been taken for granted that the same is true in the cases of interest to quantum mechanics.
12. **Summary: the objective core of the advanced action interpretation.**

Understanding the anthropocentric origins of the asymmetry of dependency is thus an important step towards appreciating the attractions and physical significance of an advanced action interpretation of quantum mechanics. On the one hand it enables us to see that despite the conventional character of this asymmetry, there is a real physical issue at stake. (Hence it counters the tendency to dismiss the approach as being either “metaphysical” or “subjective”, and hence of no relevance to physics.) On the other hand, by unravelling some the connections between our folk intuitions about causation and our place in the physical world, it helps us to see that these intuitions do not provide an authoritative guide to the issue in quantum mechanics.

In particular, the recognition of the subjectivity of causal asymmetry does not throw the baby out with the bath water, as we put it earlier, leaving no objective content to the advanced action view. The problem was simply that we didn’t have a clear impression of the distinction between the water and the baby—that is, between our subjectively-grounded intuitions concerning causal asymmetry and an issue concerning patterns of correlation in the world. Once the distinction has been drawn, however, it is possible with a little care to discard the dirty water and keep the baby.

The baby is a proposition concerning the correlational structure of the microworld, and we have seen that there are two very different forms this structure might take. There is an objective distinction between worlds which look as if they contain unidirectional causation and worlds which look as if they contain bidirectional causation (where “look as if” is to be filled out in terms of the conventionalist’s account of how the temporally asymmetric nature of agents comes to be reflected in their concept of causation). With the benefit of hindsight we can see that we have never had good reason to exclude the structure that permits interpretation in bidirectional terms. In order to be able to see this, however, it was essential to appreciate the subjective character of the interpretation.

13. **TRIPLET SHOCK LATEST!**

As some readers will already be aware, there is an interesting new class of Bell-like results in quantum mechanics, which seem to achieve Bell’s conclusions by non-statistical means. It is natural to wonder whether these new results—the Greenberger-Horne-Zeilinger (GHZ) cases, as they have become known—have a bearing on the arguments of this paper. To my knowledge, the GHZ argument has not yet been expounded in non-technical terms in the general philosophi-
cal literature. By a stroke of good fortune, however, it turns out that here too Doppelgänger has been here first. In recently de-classified research, Doppelgänger conducted further analyses of the Ypiarian police records, obtaining results strikingly parallel to those predicted by GHZ. The purpose of this section is to provide a brief exposition of these results, so as to show that the GHZ results simply add weight to the existing case for advanced action.

Doppelgänger’s clandestine investigations led him from twins to triplets. To his surprise, he found that the Ypiarian criminal code embodied special exemptions for triplets, who were excused for adultery on grounds of diminished childhood responsibility. When subject to random interrogation, then, triplets were only asked one of the two questions Are you a thief? and Are you a murderer? In records of these interrogations, Doppelgänger found that on occasions on which all three members of a set of triplets were questioned in this way, their answers always conformed to the following pattern:

\begin{align*}
\text{same*} & \quad \text{When all three triplets were asked the first question, an odd number of them said “no”.} \\
\text{diff*} & \quad \text{When two triplets were asked the second question and one the first, an even number (i.e. two or none) of them said “no”.}
\end{align*}

As in the twins case, Doppelgänger asked himself whether these results could be explained in terms of “local hidden variables”—that is, in terms of psychological factors predisposing each triplet to respond in a certain way to either of the possible questions, independently of the concurrent experiences of his or her fellow triplets. Reasoning as follows, he decided that this was impossible.

Suppose that there are such psychological factors. Given a particular set of triplets, let us write $x_1$ and $y_1$ for the factors responsible for the answer the first triplet would give to the first and second question, respectively, and similarly $x_2$, $x_3$ and $y_3$ for the corresponding factors in the second and third triplets. And let us think of these factors as having values $+1$ or $-1$, according to whether they dispose to a positive or negative answer. Then same* implies that the product of $x_1$, $x_2$ and $x_3$ is $-1$ (since it contains an odd number of negative factors); and diff* implies that each of the products $x_1 y_2 y_3$, $y_1 x_2 y_3$ and $y_1 y_2 x_3$ has value $+1$ (since it contains an even number of negative factors). Taken together these results in turn imply that the combined product

\[(x_1 x_2 x_3)(x_1 y_2 y_3)(y_1 x_2 y_3)(y_1 y_2 x_3) = (-1)(+1)(+1)(+1) = -1.
\]

This is impossible, however, since each individual factor occurs exactly twice on the left hand side, so that negative factors must cancel out. Hence local hidden variables cannot account for the observed results.

\footnote{37 The most accessible expositions are those of Mermin (1990) and Maudlin (1994), pp. 24-8. My account draws on that of Clifton, Pagonis and Pitowsky (1992).}

\footnote{38 Allegedly funded by the Copenhagen Interpretation Authority.}
Our present interest in this case lies in the fact that the triplet correlations that Doppelgänger discovered in the Ypiarian case exactly match those predicted by the recent GHZ results in quantum mechanics. The behaviour of Ypiarian triplets parallels that of sets of three spin-1/2 particles in the so-called GHZ state, when subject to combinations of spin measurements in one of two chosen directions orthogonal to their lines of flight. Particle 1 can thus have its spin measured in direction $x_1$ or direction $y_1$, particle 2 in direction $x_2$ or $y_2$ and particle 3 in direction $x_3$ or $y_3$. An argument exactly parallel to the one just given shows that a local hidden variable theory cannot reproduce the predictions of quantum mechanics concerning combinations of such measurements.

Notice that unlike Bell’s Theorem, the argument is combinatorial rather than statistical in character. Like Bell’s Theorem, however, the GHZ argument depends on the Independence Assumption. That is, it requires the assumption that the values of hidden variables do not depend on what is to happen to the particles in question in the future—in particular, on the settings of future spin measurements. In the presentation of the argument by Clifton, Pagonis and Pitowsky (1992) for example (whose terminology I have borrowed above, in describing the Ypiarian parallel), the assumption is introduced in the following passage:

[W]e need to assume that $\lambda$ [the set of hidden variables] is compatible with all four measurement combinations. This will be so if: (a) the settings are all fixed just before the measurement events occur, so that $\lambda$ lies in the backwards light-cones of the setting events, and (b) the choice of which settings to fix is determined by (pseudo-)random number generators whose causal history is sufficiently disentangled from $\lambda$. (1992, p. 117)

The advanced action interpretation will simply reject proposition (a), of course. In the present context the important point is that the GHZ argument provides no new argument against the advanced action interpretation. On the contrary, if anything, it simply adds impressive new weight to the view that the alternatives to advanced action are metaphysically unpalatable.

14. Conclusion.

The metaphysical temptation that Bell noticed is a much better offer than he himself took it to be. It doesn’t raise any new difficulties for free will, or any awkward causal paradoxes. Its objective core seems to boil down to a rather harmless proposal concerning the correlational structure of the microworld—indeed, a proposal which seems independently attractive on symmetry grounds. Yet it has the advantages that Bell seems to have recognised: it offers us a route to an Einsteinian realism about quantum mechanics which is local, and

\[39\] Proposition (b) serves to exclude the alternative path to rejection of the Independence Assumption which we mentioned in note 4.
therefore compatible with special relativity; and which shares the well known advantages of the Einsteinian view that quantum mechanics is incomplete. It is time that this neglected approach received the attention it so richly deserves.}

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\footnote{A brief guide to further reading: the earliest, best known and certainly the most prolific advocate of an advanced action interpretation is O. Costa de Beauregard, whose papers on the topic date back to 1953. His more recent papers include (1977) and (1979). (Costa de Beauregard’s views are discussed by d’Espagnat in the works mentioned in note 25.) The most highly developed version of the interpretation seems to be that of J. G. Cramer (1986, 1988). In the former paper (pp. 684-5) Cramer compares his view to earlier advanced action interpretations. The theoretical basis of Cramer’s approach seems to me to be questionable, however: see my (1991b), pp. 973-4. Other advocates of advanced action in quantum mechanics include Davidson (1976), Rietdijk (1978), Schulman (1986) and Sutherland (1983). See also Price (1984).}
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