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Samuel Pintuck
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AND
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PREFACE

The philosophy of science is concerned with the assumptions, foundations, methods and implications of science. It is also concerned with the use and merit of science and sometimes overlaps metaphysics and epistemology by exploring whether scientific results are actually a study of truth. In this book, the authors present current research in the study of the philosophy of science including explaining global interactions; Poincare's enigmatic relationship with logic and the infinite; providing analogous insight regarding ontological issues and a conceptual parallel between Heisenberg's and Bohm's interpretation of quantum mechanics.

Chapter 1 - Several variants of Benardete's paradox lead naturally to the existence of global interactions and there are also other variants that cannot be understood in terms of global interaction because they are examples of actions with no interaction at all. The model of Benardete's paradox employed in this chapter enables us to see how both global interaction and action without interaction can emerge as different manifestations of the same explanatory schema, obeying to that extent a common "deep reason". Finally, in the light of these results, I shall consider Shackel's criticism (2005) of several current diagnoses concerning Benardete's paradox.

Chapter 2 - Traditionally, Henri Poincaré (1845 - 1912) has been recognized as a pioneer in the discovery of predicative set theory. Less attention, however, has been attributed to the importance of intuition to his interpretation of what it means to exist in the domain of pure mathematics. This imbalance is hard to justify in terms of Poincaré's own philosophical writings, as his contentions with his contemporaries – most notably, the logicists – are typified by appeals to the indispensability of intuition as a foundation for mathematics. The value of predicativism as a means of circumventing the set-theoretic paradoxes and indeed, of rendering mathematical definitions and proofs more transparent is well-recognized. Nevertheless, the associated systems are also noted for their restrictive nature in terms of proof-theoretic strength. It is important, therefore, to take a fresh look at Poincaré's philosophical writings to establish how the divergence between his foundational arguments and his reputation as a predicativist may have emerged. In this chapter, I shall offer new insight into the relevance of intuition to Poincaré's criteria for set existence and in particular, his requirement that infinite sets should be surveyable. On this basis, I shall argue that Poincaréan set theory ought to be more liberal than has traditionally been assumed. In exploring the above criteria, I shall also revisit Poincaré's unexplained affinity towards classical logic. By appealing to the influence of Aristotle's writings on Poincaré's interpretation of logic, I shall show that his ambiguous reference to the intuition of pure number as that of pure logical forms invites further exploration. Thus, I shall argue that Poincaré's treatment of the principles of Non-contradiction and Excluded Middle as necessarily true has its roots in logical intuition – a variety of intuition which he neglects at the cost of his own anti-logicist stance. These findings serve as an extension of my recent work on the nature of mathematical intuition. As such, they provide some essential groundwork for developing an alternative set theory with the potential to create a more successful synergy between Poincaré's philosophy and practice in pure mathematics.

Chapter 3 - In this chapter, the authors argue that both the problem of quantum indistinguishability in the philosophy of physics and the problem of identity in structures in the philosophy of mathematics are identical in a certain relevant sense; i.e., that they are two instances of the same general problem. This favors the idea that certain ontological questions are common to different domains, in spite of the specificity of each domain; hence, the solutions proposed in one of the domains may be extrapolated and adapted to the others.

Chapter 4 - It is undeniable that quantum mechanics has enjoyed nothing less than staggering success in almost every way that scientific theories are judged. Although it is a theory whose laws govern the unimaginably small, it has had a profound impact on the everyday lives of people.

Chapter 5 - Recent research in science education has shown considerable interest in the history, philosophy of science and epistemological issues. This, relatively new approach to teaching and research in science education requires a brief recapitulation of the debates and controversies in history and philosophy of science.

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Chapter 1

GLOBAL ACTION AND ACTION WITHOUT INTERACTION

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ABSTRACT

Several variants of Benardete's paradox lead naturally to the existence of global interactions and there are also other variants that cannot be understood in terms of global interaction because they are examples of actions with no interaction at all. The model of Benardete's paradox employed in this chapter enables us to see how both global interaction and action without interaction can emerge as different manifestations of the same explanatory schema, obeying to that extent a common "deep reason". Finally, in the light of these results, I shall consider Shackel's criticism (2005) of several current diagnoses concerning Benardete's paradox.

1. INTRODUCTION

In "A Variant of Benardete's Paradox" (2003), I showed that several variants of Benardete's paradox lead naturally to the existence of global interactions, and in "Action without Interaction" (2005) I showed that there are also other variants that cannot be understood in terms of global interaction because they are examples of actions with no interaction at all. The latter result in particular required postulating two things:

PW(B): There is no positive lower bound on the possible length of time that a change in the position of a particle may take,

and

C: Particle world lines do not have beginning or end points.

PW(B) is *de facto* incompatible with a relativist universe such as, for example, the one in which we live. It would therefore be desirable to have to hand an argument for the possibility of action without interaction that did not depend on this postulate. This is one of the things I shall be doing here: in the present article only the use of the usual postulates of continuity ("Particle world lines are continuous") and connectedness ("If a particle exists in two given instants of time it also exists in every instant of time between them") (1) will be crucial, although the latter postulate is not required to prove the existence of action without interaction. But the model of Benardete's paradox employed to do so also enables us to see how both global interaction and action without interaction can emerge as different manifestations of the same explanatory schema, obeying to that extent a common "deep reason". Finally, in the light of these results, I shall consider Shackel's criticism (2005) of several current diagnoses concerning the Benardete paradox, in particular the one given in my, "A Variant of Benardete's Paradox"

2. Explaining Global Interaction

In the model of Benardete's paradox I use in this chapter, I shall assume, for simplicity's sake, unidimensional motion (as is usual) and I shall assume that particle p is moving to $\Delta<t<0$ in the region $x<0$ of axis X according to the law $x = t$. Another assumption is that only the gods (a numerable infinity of gods: God_1, God_2, God_3 …) may affect p in one way or another. Following the model of the original Benardete's paradox, we will suppose that, for each n, God_n controls point $x_n = 1/n$ of space exclusively: this control consists in God_n being able to stop or not, at will, particle p at $x_n = 1/n$. The idea is that

God_n acts on the particle at $x_n = 1/n$ stopping it there or does not act on it at all at $x_n = 1/n$. This way, an individual God may not perform any action other than stopping the particle.[(2)]

Let us suppose that the action plan for God_n ($\forall n$) is as follows:

(1) God_n stops p at $x_n = 1/n$ if and only if no God_{n+m} ($m \geq 1$) stops p at $x_{n+m} = 1/(n+m)$ (n = 1, 2, 3 …)

Clearly (1) leads to contradiction. Either no God stops p or at least one does so. If none stops it, then under (1), God_1 stops p at $x_1 = 1$, clearly a contradiction. If at least one God stops it, for example God_G, then under (1) no God_{G+m} ($m \geq 1$) stops it and, in consequence, no God_{G+m+1} ($m \geq 1$) stops it. But this last leads under (1) to God_{G+1} stopping the particle, another contradiction. My first contribution in this chapter (central to what follows) will be to explain why there is a contradiction here. There is a contradiction, as we have just seen; nevertheless I maintain that we may only say that we really understand the situation if we can explain why this is so, why (1) is defective. The key lies in seeing that in (1) only the more or less arbitrary condition that God_n imposes for acting (stopping p) is reflected, and that there is in fact another condition, one that does not depend at all on the will of God_n but (assuming, as we are, that God_n has the power to stop p at x_n) on what it actually means for p to stop at $x_n = 1/n$, and which is therefore the condition of the possibility of such a stop. To see this clearly, let us consider the sentence S: the individual I* stops particle p at the point x. S is equivalent to sentence A: the individual I* actualizes the possibility of particle p stopping at point x. Therefore a necessary and sufficient condition for S may be formulated as a conjunction of a necessary and sufficient condition for the possibility of particle p stopping at point x (assuming that I* has the power to stop p at x) with a condition necessary and sufficient for individual I* to actualize such a (now guaranteed) possibility. A necessary and sufficient condition for it to be possible for particle p to stop at point x is, fairly obviously, that the particle is at x in some moment t, such that there are instants of time previous, but arbitrarily close, to t in which the particle is at points different from x. This last is eminently reasonable because if, at least in the immediate past of t, the particle has never been at points different from x then it must have stopped before t (or perhaps never, for the trivial reason that it was never at points different from x). In more precise terms, it is possible for particle p to stop at point x if and only if it is possible for particle p to stop at point x in some instant t if and only if there is at least one instant t such that p is at x in t and $\forall$ $\varepsilon > 0$ there is at least one instant belonging to the interval $(t - \varepsilon, t)$ in which p is at a point different from x. Also, a necessary and sufficient condition for the individual I* to actualize the (now guaranteed) possibility of particle p stopping at point x may take a wide variety of different (and not necessarily mutually equivalent) forms owing to the fact that it will contain in general the more or less arbitrary criterion that I* decides to follow. In the case of the model of Benardete's paradox introduced above, this necessary and sufficient condition for God_n is of course given by the term on the right in equivalence (1). The defect in (1) is now clear: the necessary and sufficient condition for the possibility of p stopping at the different $x_n = 1/n$ points has not been included there. The action plan of God_n ($\forall n$) must therefore be written as follows:

(2) God_n stops p at $x_n = 1/n$ if and only if : no God_{n+m} ($m \geq 1$) stops p at $x_{n+m} = 1/(n+m)$ and there is at least one instant t_n such that: p is at x_n at t_n and $\forall$ $\varepsilon > 0$ there is at least one instant in the interval $(t_n - \varepsilon, t_n)$ in which p is at a point different from x_n

How does this affect our diagnosis of the situation? Given (2), the fact that (1) leads to contradiction indicates that it cannot be true that, for all n:

(3) there exists at least one instant t_n such that: p is at x_n at t_n and $\forall$ $\varepsilon > 0$ there is at least one instant in the interval $(t_n - \varepsilon, t_n)$ in which p is at a point different from $x_n = 1/n$

It is in fact easy to see that (3) is false for any n. To prove this, it is enough to use the postulates of continuity and connectedness (these being intuitively plausible and, following what was said at the beginning, all that is required, besides the powers we have supposed for the gods, to demonstrate both the possibility of global interaction and action without interaction). In fact, if (3) were true for a certain n = N then p would be at $x_N = 1/N$ at a certain instant t_N. This implies that none of the God_{N+m} ($m \geq 1$) gods would have stopped the particle, otherwise this would have stayed at some x_{N+m} =

1/(N+m) and would never have arrived at point $x_N = 1/N$. However, to get to $x_N = 1/N$, particle p has had to pass through the x_{N+m} points at certain t_{N+m} instants (a requirement of the postulate of connectedness as, to begin with, p was in the region x<0 and we know that its space-time trajectory must be continuous). But this means that for any m≥1 there is at least one t_{N+m} instant such that: p is at x_{N+m} at t_{N+m} and $\forall\ \varepsilon > 0$ there is at least one instant in the interval $(t_{N+m} - \varepsilon, t_{N+m})$ in which p is at a point different from x_{N+m}, Therefore, for any m≥1 we deduce from (2) that:

(2.2) God_{N+m} stops p at $x_{N+m} = 1/(N+m)$ if and only if no God_{N+m+q} (q≥1) stops p at $x_{N+m+q} = 1/(N+m+q)$

Since no God_{N+m} stops p it follows that no God_{N+m+q} (q≥1) stops it and, in line with (2.2), that all the God_{N+m} gods stop the particle. This contradiction shows that the assumption we started with, i.e. that (3) is true for a certain n = N, is false. So (3) is false for all n. Therefore, whatever n is:

(4) for all instants t_n, if p is at $x_n = 1/n$ at t_n then $\exists\ \varepsilon > 0$ such that for all instants belonging to the interval $(t_n - \varepsilon, t_n)$ p is not at a point different from $x_n = 1/n$

It is clear that if, after t = Δ<0, p is ever at some point $x_n = 1/n$ (n = 1, 2, 3, ,,,), it will be so for instants of time t≥0 because, under the hypothesis, it is in the region x< 0 for Δ<t<0. And if t*≥0 is an instant in which p is at some point $x_n = 1/n$ then, in any instant prior to t* and after Δ, p must be at some point because, by virtue of the postulate of connectedness, if it exists for Δ<t<0 and for a certain t*≥0, it must necessarily also exist in the non-negative intermediate instants (if there are any). That said, it is clear from (4) that if p is actually at some non-negative time (i.e. in some $t_n \geq 0$) at some point $x_n = 1/n$ (n= 1, 2, 3, ,,,) then it will remain there at rest for ever because not being at a point different from $x_n = 1/n$ during a certain non-null interval $(t_n - \varepsilon, t_n)$, and since we know it will be at some point in each instant of that interval, it follows that it will be at $x_n = 1/n$ during the interval $(t_n - \varepsilon, t_n)$, i.e. it will be at rest in $x_n = 1/n$ during the interval $(t_n - \varepsilon, t_n)$. But then it will remain at rest at $x_n = 1/n$ for ever because it will have been stopped there by God_n (the only one controlling this particular point) and we may suppose that if any God stops p at some point it keeps it there for ever. So, since if p is ever at $t_n \geq 0$ at some point $x_n = 1/n$ (n= 1, 2, 3, …) it will remain there for ever and that for $\Delta < t < 0$ p is in the region $x<0$, the postulate of connectedness leads to the conclusion that p can never be in the region $x>0$. Consequently p will be stopped at $x=0$ or, alternatively, will rebound backwards at it. This way we recover the idea of global interaction introduced in "A Variant of Benardete's Paradox" (2003): no God interacts individually with p, but the set of Gods does so globally by preventing p from reaching the region $x>0$. The gain here over what was done then is that there the idea of global interaction was a hypothesis that required justification to make it plausible. Here, to the contrary, it is the consequence of a much more fundamental requirement, that of also making explicit the conditions for the possibility for any act of detention performable by the gods, and not merely the conditions of actualization of that possibility as if the possibility itself were already guaranteed. Although the latter (i.e. the mere conditions of actualization) is sufficient in the immense majority of contexts that we can usually imagine (and certainly in all ordinary contexts), Benardete's paradox reminds us that it is not always so.

In fact, in Benardete's original paradox, the action plan for God_n (n = 1, 2, 3, …) is not given by (1) but by the following: God_n stops p at point $x_n = 1/n$ should p actually arrive there. However, even in this case, the above discussion remains fully pertinent and valid because (1) continues to provide the necessary and sufficient condition for God_n to actualize the possibility of p stopping at $x_n = 1/n$ ASSUMING THAT THIS POSSIBILITY IS ALREADY GUARANTEED. Therefore (1) is defective for the same reason as before: it takes no account of the necessary and sufficient condition for the possibility of p stopping at $x_n = 1/n$. When this condition is added, we arrive at (2) and now from here the existence of a global interaction follows (under the postulates of continuity and connectedness) as a logical consequence.[3]

Before concluding this section, I would like to comment briefly on the indeterminism involved in the evolution of particle p when I say that p will be stopped at x = 0 or, alternatively, will rebound backwards at that point. One might think this conclusion makes my model less interesting, for the following reason: as any given force must have a unique effect on a particle, classical physics would seem to be bound up with determinism, so that cases of indeterministic evolution (and my model presents one of these cases) would not be consistent with it. But this conclusion is erroneous. Although a given force should have a single effect when acting on a particle, this does not turn classical physics into a deterministic theory because there are situations where it is not determined which actual force acts on a particle. Consider for example the case of three identical rigid spheres in line: two of them, B and C, at rest and in contact while the third, A, approaches them from the left at unit velocity. Classical physics does not permit us to determine the final state of this process. A may be stopped while C moves to the right. But it is also possible for both B and C to move to the right while A rebounds to the left. Given the force that acts on A (which in this case is specified not by a function but by a Dirac δ distribution) we will know exactly how it will move, the problem is that classical physics does not tell us what force acts on A: it leaves open a range of possibilities, albeit fairly limited. So the indeterminism linked to the global interaction of the gods with particle p does not *per se* make my model inconsistent with classical physics. Indeed, if we use the model of God_n as a particle q_n identical to p and placed at rest at $x_n = 1/n$ before $t = 0$ (the model introduced in note (3)) then the analysis of the global collision in Pérez Laraudogoitia 2005b, pp. 327-330, shows that classical mechanics does not determine which of the two destinies p follows: whether it is stopped or rebounds. Further, both here and in the case of the spheres A, B, C either of the two destinies of p (or A) is compatible with the elastic nature of the collision (multiple in A's case and global for p): the elasticity of the collision neither excludes p (or A) rebounding nor excludes the possibility of it stopping and thus it is compatible with indeterminism (in both cases we might suppose, without being inconsistent, that all the collisions involved are elastic).

3. Unifying Global Interaction and Action without Interaction

Let us see now how the same explanatory schema that has enabled us to demonstrate the possibility of global interaction also enables us to demonstrate the possibility of action without interaction. The modifications needed to the previous proof tend to the trivial and it is particularly important that the only necessary postulate is the one concerning the continuity of a particle's worldline. The interest and the relevance of this argument, which does not require the use of the postulate PW(B), will be immediately appreciable. All we have to do is take the limit $n \to \infty$ in the model of Benardete's paradox considered in the previous section. This of course only affects the terms of that model that have metric value, so that fractions $1/n$ and $1/(n + m)$ are now substituted by 0 (as $1/n \rightarrow 0$ and $1/(n + m) \rightarrow 0$, given that $n \rightarrow \infty$). Contrariwise, terms such as God_n, God_{n+m}, x_n, x_{n+m} and t_n are simply denotative, being replaceable, in principle, by arbitrary proper names, which means they would not be affected. Solely for simplicity's sake, I shall write $x = 0$ instead of $x_n = 0$ or $x_{n+m} = 0$. In consequence, in the new model of Benardete's paradox there are only two basic differences with regard to the previous model. The first is that, for each n, God_n controls the point x=0 exclusively. The second, that the action plan for God_n ($\forall n$) is as follows:

(1*)God_n stops p at x=0 if and only if no God_{n+m} ($m \geq 1$) stops p at x=0 (n= 1, 2, 3, ...)

As occurred with (1), (1*) leads likewise to contradiction, and following the same path that took us from (1) to (2) the action plan of God_n ($\forall n$) must be written as:

(2*) God_n stops p at x=0 if and only if : no God_{n+m} ($m \geq 1$) stops p at x=0 and there is at least one instant t_n such that p is at x=0 in t_n and $\forall\ \varepsilon > 0$ there is at least one instant in the interval $(t_n - \varepsilon, t_n)$ in which p is at a point different from x=0

Once again, the contradiction found from (1*) indicates that it cannot be true that, for all n:

(3*) there is at least an instant t_n such that: p is at x=0 in t_n and $\forall\ \varepsilon > 0$ there is at least one instant in the interval $(t_n - \varepsilon, t_n)$ in which p is at a point different from x=0

and now it is also easy (it is in fact trivial) to prove that (3*) must be false for any n. Indeed, let N be a value of n for which (3*) is false, i.e. that it holds that:

it is false that there is at least one instant t_N such that: p is at x=0 in t_N and $\forall\ \varepsilon > 0$ there is at least one instant in the interval $(t_N - \varepsilon, t_N)$ in which p is at a point different from x=0

But in this sentence t_N is a bound variable and the symbol N only appears in it as a subscript of t, which means that N could be replaced by any other term n denoting a number without altering its truth value or even its meaning. Therefore, whatever n is:

(4*) for any instant t_n, if p is at x=0 in t_n then $\exists\ \varepsilon > 0$ such that for all instants belonging to the interval $(t_n - \varepsilon, t_n)$ p is not at a point different from x=0

From (4*), through elimination of the universal:

if p is at x=0 in t=0 then $\exists\ \varepsilon > 0$ such that for all instant belonging to the interval $(-\varepsilon, 0)$ p is not at a point different from x=0.

Now let us suppose that p is at x=0 in t=0. Then in some non-null interval of time $(-\varepsilon, 0)$ p will not be at a point different from x=0. But this contradicts the initial condition that for $\Delta<t<0$ p is in the region x<0. So p cannot be at x=0 in t=0. Since, according to our initial condition, p moves according to the law x=t for $\Delta<t<0$, the postulate of continuity implies that p cannot be in t=0 at some point $x \neq 0$ either. It follows that in t=0 p cannot be at any point in space, and, as for $\Delta<t<0$ it was moving freely (in the region x<0) this means that p disappears suddenly at t=0 (this is what it means to say it cannot be anywhere in t=0) without having been disturbed by any interaction whatsoever.[(4)] We thus recover the idea of action without interaction introduced in "Action without Interaction" (2005): no god interacts individually with p or acts individually on p; neither does the set of gods interact globally with p, although it does act globally on it, without any interaction, by making it disappear in t=0. Part of the gain here over what was done then is the economy of postulates, continuity alone being required (without connectedness and, above all, without PW(B)). But now the action without interaction also obeys the same "deep reason" as the global interaction given above: the need to make explicit also the conditions of possibility of any act of detention performable by the gods and not merely the conditions for the actualization of that possibility as if the possibility itself were already guaranteed. Note that, in all this, the statement that in t = 0 p cannot be at any point in space does not express a mere possibility that I decide to choose from a range of alternatives incompatible with it, although possible as well. It is rather a strict logical consequence of (2*) together with the pertinent initial conditions (namely, that