Indeterminism and Indeterminacy

Katherine Hawley, *Analysis*, 58.2 (1998) pp. 101-106.

1. E.J. Lowe claims that quantum physics provides examples of ontic indeterminacy, of vagueness in the world. Any such claim must confront the Evans-Salmon argument to the effect that the notion of ontic indeterminacy is simply incoherent (Evans 1978, Salmon 1981: 243-46). Lowe argues that a standard version of the Evans-Salmon argument fails quite generally (Lowe 1994). Harold Noonan (1995) has outlined a non-standard version of the argument, but Lowe argues that this non-standard version fails for specifically quantum mechanical reasons (Lowe 1997). He claims that it is perfectly coherent to suppose that his quantum case is an example of ontic indeterminacy.

I will not discuss Lowe's objection to the standard Evans-Salmon argument. Instead, I will argue that Lowe's quantum-mechanical objection to the non-standard Evans-Salmon argument fails. Whilst he posits quantum indeterminacy, Lowe fails to take seriously the implications of any such indeterminacy. I will argue that it is, after all, incoherent to claim ontic indeterminacy in the situation he describes.

2. Lowe's case is the following. An electron *a* is absorbed by an atom and becomes entangled with the electron in the outer shell of the atom. Some time later, an electron *b* is emitted from the atom. It seems indeterminate whether *a* is identical to *b*, and, Lowe claims, this is ontic indeterminacy, not epistemic or semantic indeterminacy. It is not simply that we cannot tell whether *a* is identical to *b*, nor is it that we have been imprecise in assigning referents to the names '*a*' and '*b*'. Rather, Lowe claims, the world beyond us is indeterminate with respect to whether *a* and *b* are identical.

Lowe explains why this claim might -- in his view mistakenly -- be thought incoherent. 'Let t_0 be the time of entanglement following the capture of *a* and prior to the emission of *b*; and let t_1 be some time after the emission of *b*. Then, I accept, at t_1 it was *not* indeterminate whether *b* had been emitted but *was* indeterminate whether *a* had been emitted.' (All quotations are from Lowe 1997: 90-91)

This might seem to provide raw material for an argument that Lowe's ontic indeterminacy claim is incoherent. This Evans-Salmon argument runs as follows. Assume for *reductio* that it is ontically indeterminate whether *a* is identical to *b*. Now, *a* is such that at t_1 it is indeterminate whether it has been emitted. But *b* is not such that at t_1 it is indeterminate whether it has been emitted. So *a* and *b* differ in at least one property, and are, contrary to assumption, determinately distinct. The assumption of ontic indeterminacy entails the denial of ontic indeterminacy. If it *is* indeterminate whether *a* is identical to *b*, this must be for either semantic or epistemic reasons.

In response, Lowe claims that 'at t_0 it was indeterminate whether *b* was going to be emitted' and that 'Granting that there is a property that is assignable to *a* in virtue of the fact that at t_1 it was indeterminate whether *a* had been emitted from the atom, we can nonetheless see that there is no reason to suppose that this property is determinately distinct from the property that is assignable to *b* in virtue of the fact that at t_0 it was indeterminate whether *b* was going to be emitted from the atom.'

It seemed that *a* has a property that *b* lacks. But, says Lowe, *b does* have a property that is not determinately different from the relevant property of *a*, and thus *a* and *b* are not determinately different. Lowe argues that the ontic indeterminacy claim does not, after all, lead to contradiction.

I will not discuss whether the 'two' properties are determinately distinct, since I deny that *b* has the property attributed to it by Lowe. I deny that at t_0 it was indeterminate whether *b* was going to be emitted from the atom. If I am right, then the non-standard Evans-Salmon argument outlined above succeeds, and Lowe's ontic indeterminacy claim *does* lead to contradiction. If there is any indeterminacy in the identity of *a* and *b*, then it is either epistemic or semantic indeterminacy.

3. Consider *P*, the property of being emitted between t_0 and t_1. According to Lowe, at t_0 it is indeterminate whether *b* has *P*, whilst at t_1 it is determinate that *b* has *P*. Now, *b* does *not* simply acquire *P* at the time of emission. (If this were the case, then at t_0 it would be determinate that *b* does not have *P*.) Rather, the fact that *b* has *P* somehow becomes determinate between t_0 and t_1.

Why believe that a fact becomes determinate as time passes? It is possible to argue that the future is open, that there are *in general* no determinate facts about the future. I take it, however, that Lowe is not defending a thesis of general ontological asymmetry between the past and the future.

Instead, this case is supposed to be special. 'The important feature of the example is, of course, that at time t_0 these two electrons [*a* and *b*] exist in an 'entangled' or 'superposed' state, as a consequence of which there is *no fact of the matter* as to *which* of them is later emitted and *which* of them later remains within the outer shell of the atom.' This reiteration of the disputed claim may reveal Lowe's argument.

Lowe claims that at t_0 it is indeterminate whether *b* will be emitted, and I disagree. What feature of the entangled state could support Lowe's claim? I will consider and eliminate the possibility that the claim is supported by either quantum indeterminism or else by the granted assumption that it is indeterminate whether *a* is emitted. Then I will argue that any other grounds Lowe might have for his claim about *b* would provide equal grounds for the implausible claim that at t_0 it is indeterminate whether *a* has been absorbed.

4. First, indeterminism. On many interpretations of quantum mechanics, the laws of nature, together with a complete qualitative description of the situation up to time t_0, entail neither that *b* will be emitted nor that *b* will not be emitted. It is purely a matter of chance which electron is later emitted, and thus it is *undetermined* at t_0 whether *b* will be emitted. Indeterminism does not, however, give us reason to believe that it is *indeterminate* at t_0 whether *b* will later be emitted, that there is no fact of the matter.

Lowe recognises our reluctance to believe that at t_0 it is indeterminate whether *b* will be emitted. He hints that we are misled by the explicit introduction of '*b*' as a name for the emitted electron, whichever electron that turns out to be. Yet our subject matter is ontic -- not semantic -- indeterminacy, so any determinate feature of the emitted electron will also be a determinate feature of *b*, since these are one and the same particle. It is true that at t_0 it is not *determined* that the electron that will be emitted (i.e. *b*) will be emitted. It is by chance that *b* is emitted, even though *b is* the emitted electron, and is introduced as such. Nevertheless, indeterminism gives us no reason to believe that at t_0 it is *indeterminate* whether the electron that will be emitted (i.e. *b*) will be emitted.

5. Second, consider the following possible argument. By assumption, it is ontically indeterminate at t_0 whether *a* is later emitted. Call the entangled electron which is not *a*, '*e*'. It is indeterminate whether *e* is later emitted. (If there were a fact of the matter about *e*, there would be a corresponding fact of the matter about *a*, contrary to assumption.) So each of the entangled electrons is such that it is indeterminate at t_0 whether that electron is later emitted.

But *b* is supposed to be one of the entangled electrons. 'It is uncontentious that two electrons, *a* and *b*, both exist throughout a period of time which begins before the capture of one of them and ends after the emission of one of them.' Therefore, runs the imagined argument, *b* must have any property shared by *a* and *e*. So, like *a* and *e*, *b* is such that it is indeterminate at t_0 whether it is later emitted. This argument is suggested by Lowe's closing lines: 'For if it is indeterminate whether one of the 'entangled' electrons, *a*, is later located outside the atom's outer shell, by the same token it is indeterminate whether the other 'entangled' electron, *b*, is later located outside the atom's outer shell.'

The claim is that the ontic indeterminacy assumption entails that at t_0 it is indeterminate whether *b* is later emitted. If correct, this could undermine the Evans-Salmon argument that the ontic indeterminacy assumption is incoherent. The strategy is sound, but the argument fails, since it does not take seriously the ontic indeterminacy assumption.

It is supposed to be both indeterminate whether *b* is identical to *a* and indeterminate whether *b* is identical to *e*. This is *not* to say that either *b* is identical to *a* or *b* is identical to *e* (at least, not in the classical sense of 'or'). Indeed, ontic indeterminacy means that *b* is *not* determinately identical to *a* and is *not* determinately identical to *e*. There is no reason to suppose that the properties of *b* are those properties shared by *a* and *e*, and thus no reason to suppose that *b* is such that at t_0 it is indeterminate whether it will be emitted.

The two-slit experiment illustrates the consequences of taking indeterminacy to be ontic. A quantum particle is fired at an opaque barrier with two slits, and its final position is recorded on a screen beyond the barrier. It is indeterminate which slit the particle passes through. This is *not* to say that the particle must have any property which it would possess if it had passed either through one slit or through the other. Indeed, the particle reaches positions which would be inaccessible if it had determinately passed through either one slit or the other. Likewise, *b* can have properties neither *a* nor *e* possesses, and it can be determinate at t_0 that *b* will be emitted. Ontic indeterminacy is no reason to believe that at t_0 it is indeterminate whether *b* will be emitted.

6. Finally, consider the temporal symmetry of the situation. We have ruled out a general asymmetry between past and future, and seen that the temporal asymmetry of indeterminism is irrelevant. Lowe asks us to believe that before emission it was indeterminate whether *b* was going to be emitted and that after emission it was determinate that *b* had been emitted. Then, although it is determinate before absorption that *a* will be absorbed, temporal symmetry suggests we should believe that after absorption it is indeterminate whether *a* has been absorbed.

When does the fact of absorption supposedly become indeterminate? At the moment of absorption, or some time later? It is apparent that we have no reason to believe that a fact about *a* becomes indeterminate as time passes. In the same way, we have no reason to believe that a fact about *b* becomes determinate as time passes.

7. Neither indeterminism nor ontic indeterminacy supports Lowe's claim that it is ontically indeterminate at t_0 whether *b* will be emitted. Lowe *could* continue to claim that a fact about *b* becomes determinate as time passes, since I have not shown this claim to be incoherent. Nevertheless, we should recognise that he has given us no reason to believe this, not even if we are initially willing to believe that it is ontically indeterminate at t_0 whether *a* will be emitted.

The implausibility of the symmetrical claim about *a* casts further doubt on the ungrounded claim about *b*. We should also recall that even if Lowe continues to claim that it *is* indeterminate at t_0 whether *b* will be emitted, he must still show that this renders *a* and *b* indiscernible, given that it is determinate at t_1 that *b* has been emitted and yet indeterminate at t_1 whether *a* has been emitted.

If Lowe gives up his claim, then the Evans-Salmon argument succeeds: the supposition that it is ontically indeterminate whether *a* is identical to *b* turns out to be incoherent.

8. If it *is* indeterminate whether *a* is identical to *b*, then the indeterminacy is epistemic, or else semantic, as Noonan (1995) suggests. Noonan diagnoses imprecision in the reference of '*a*' and of '*b*', a standard way of explaining apparent indeterminacy of identity over time in classical cases.

Are there special reasons to rule out semantic indeterminacy in this non-classical case? Entangled particles are qualitatively indistinguishable. The imprecision in the reference of '*a*' and of '*b*' is thus in principle irresolvable, since nothing we could say could fix reference during the period of entanglement. Nevertheless, irresolvable semantic indeterminacy is still semantic indeterminacy, and can explain any indeterminacy in the question of whether *a* is identical to *b*.

Lowe himself would rule out the semantic indeterminacy explanation, since the most natural way of developing this presupposes a temporal-parts view of persistence, a view which he rejects. His remaining options are either to count the indeterminacy as epistemic, or to maintain that it is determinate whether *a* and *b* are identical. Perhaps no particle survives either absorption or emission; *a* and *b* would then be determinately distinct.

9. In a different case, however, ontic indeterminacy claims may be coherent. For an Evans-Salmon argument against ontic indeterminacy to succeed, the 'two' objects in question must determinately differ in at least one property. Lowe (1994) argues persuasively that identity-*involving* properties (like the property of being determinately identical to *a*) do not suffice to distinguish indeterminately identical objects. His ontic indeterminacy claim fails only because the particles *a* and *b* in his example are distinguished by other, identity-*free* properties, by differences with respect to whether they are emitted from the atom.

Now, however, imagine particles which exist only during the period of entanglement. The indiscernibility of such particles ensures that no distinguishing properties are available to form the basis of Evans-Salmon arguments. If ontic indeterminacy claims in such cases are incoherent, it is not because of Evans-Salmon arguments.

Moreover, ontic indeterminacy claims in such cases may be motivated as well as appearing coherent. I have not discussed the sense in which the system in the entangled state is greater than the sum of its parts (see French and Krause 1995 and the references therein). This feature of entanglement may cast a conceptual shadow upon talk of individuals in the entangled state, and this shadow may prompt talk of ontic indeterminacy.

Suggestions of ontic indeterminacy may be coherent and perhaps also motivated within the entangled state, but both the motivation and the coherence are of limited scope. Talk of particles which are first outside and then within the entangled state is incompatible with talk of ontic indeterminacy. For particles like Lowe's *a* and *b*, which are supposed to survive absorption or emission, ontic indeterminacy is ruled out[1].

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[1]Many thanks to Steven French, Joel Katzav, Peter Smith and especially James Ladyman.