Causation, Time Symmetry and Russell's Directionality Argument

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In a recent publication for the project (published version; preprint) Matt Farr (Centre for Time, Sydney) and Alexander Reutlinger (Munich Center for Mathematical Philosophy) assess whether the time symmetry of physical theories excludes causation from the picture of the world given by fundamental physics.

Bertrand Russell (1913) argued that causation is "a relic of a bygone age," famously comparing it to the British monarchy in that each survives "only because it is erroneously supposed to do no harm" (more of that here). Russell's contention is that fundamental physics simply does not concern itself with anything suitably related to our everyday notion of cause. A primary reason for this concerns the role of time in physics.

The 'folk' concept of causation has a couple of key features that correlate with the folk understanding of time. *Firstly*, **Directionality:** the direction of causation aligns with the direction from past to future: if *A* causes *B*, then *A* must be earlier than *B*. It is central to our understanding of causation that what we do now can affect future events, but not past events. If I were able to make decisions *now* that influence events in my past, then there is a sense in which causality would be violated. (This is not to say that it is incoherent for there to be past-directed causes; there appears to be logical space for backwards-in-time causation in quantum mechanics.) *Secondly*, and perhaps more subtly, **Asymmetry:** we generally hold that causation is *asymmetric* – there is a basic distinction between *cause* and *effect* insofar as *if A* causes *B*, then it follows that *B* does not cause *A*. Among other things, this rules out causal loops, such as being one's own father, which although not being an outright logical impossibility, is curiously counterintuitive. This matches with the standard intuition that time is *open* – it does not go back on itself. We can see that Asymmetry is more basic than Directionality insofar as causation can have a direction *only if* there is a distinction between causes and effects: *if* Asymmetry fails, then so does Directionality.

So, how does fundamental physics threaten Directionality and Asymmetry? Firstly, the equations of fundamental physics are (given some caveats[1]) invariant under reversal in time. This

[1] It is well known that time reversal invariance is violated in some weak interactions, involving the decays of K and B mesons. It is not clear that these particular cases are relevant to the wider issue of causation in physics: even if we thought that such processes distinguish causes and effects, this says nothing about the wider issue of

means that for any sequence of states of the universe that is described by fundamental physics, the *reverse* of that sequence in time is also described by fundamental physics. This means that, in principle, any physically possible process can run both forwards and in reverse, directly undermining Asymmetry, and hence also undermining Directionality.

Does this argument work? Farr and Reutlinger argue that there is a gap in the argument here. The problem comes from inferring from time reversal invariance that *if* state *S1* can 'cause' state *S2*, then equally *S2* can cause *S1*. This is what's needed to rule out folk causation, but it is not directly entailed by time reversal invariance. The time reversal invariance of a theory tells us something about the relationship between possible states of systems that it describes, namely that if there is a possible evolution from *S1* to *S2*, then a "time reversal" transformation maps these states to other possible states *S1** and *S2** such that *S2** to *S1** is another possible evolution. Within the space of possible states defined by the theory, states *S1* and *S1** will often be *different* states – for example, in Newtonian mechanics, time reversal changes the sign of velocity, so if a point particle is moving with velocity *v*, a time reversal transformation takes us to a state defined by a particle with velocity –*v*. The interesting philosophical question here is whether *S1* and *S1**, although being different mathematical states, correspond to the same *physical* state in the world. Assuming that fundamental physics *is* invariant under time reversal, it follows that no possible measurement could distinguish between pairs of time reversed states, providing reason to think that *S1* and *S1** do pick out the same physical state. However, it is consistent to hold that these really do correspond to distinct ways the world could be, and given this, we must reject the claim that time reversal invariance is incompatible with Asymmetry and Directionality, and hence folk causation is not ruled out. So, even assuming that the fundamental laws of nature are fully time reversal invariant, it does not follow that there can be no direction of causation.

Let us suppose that the fundamental laws of nature have a feature called **One-Way Dependence** – i.e. they describe only future-directed processes and not past-directed processes. The idea is that dynamical laws should be read as describing how states depend upon *earlier* states, and importantly not upon later states. It is natural to think of physical laws in this way; for example an evolution of a system being determined by the combination of the dynamical laws and the *initial* conditions. Clearly, this way of thinking about physics is consistent with Directionality. Moreover, this is the case *regardless* of whether the relevant physics meets the criteria for being time reversal

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causation in normal cases where time reversal invariance does hold, and as such, the relationship between time reversal invariance and causation is not clarified.

invariant. However, do contemporary fundamental physical theories have this form?

It is not obvious that this is the sort of question that can be simply read-off from a physical theory. However, it does appear relevantly connected to the issue of determinism and indeterminism. Classical physics is (with some exceptions) deterministic and time reversible. It follows from this that classical physics tells us, given the complete present state of the universe, its entire history, both past and future. In this sense, classical physics is 'nomologically' (*as a matter of law*) **two-way dependent**. Quantum mechanics, conversely, is (on most popular versions) probabilistic – given a complete state of the world, the theory provides us only probabilities of future and past states. And moreover, we take these probabilities to have a time-asymmetric character: we have knowledge of certain past states, but no knowledge of future states, and we can control initial states of systems but not final states of systems. What these time asymmetries entail is that we can take the quantum probabilities to accurately predict future states, but not to accurately *retro*dict *past* states. Why? Because we can perform an experiment in which we set up a system in some initial state such that, no matter how many times we run the experiment, the initial state remains the same. In such cases, we can show that the backwards-in-time quantum probabilities fail to match the actual recorded frequencies. Does this mean that quantum mechanics is one-way dependent? Well, no. But the issue now turns to questions about the nature of probabilities, the time-asymmetry of control, and whether time-symmetric formulations of quantum mechanics ought to be preferred to standard formulations.

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