THE QUANTUM REVOLUTION IN PHILOSOPHY
RICHARD HEALEY

Reviewed by David Glick

The Quantum Revolution in Philosophy
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What is it that's revolutionary about quantum theory (QT)? Traditionally, it has been thought that the answer consists in novel and surprising aspects of the world it describes: superpositions, indeterminacy, non-locality, and so on. The central claim of Richard Healey's new book is that this is mistaken:

> Quantum theory is revolutionary not because it represents new and unfamiliar physical things and processes in the universe, but because of the way it improves our use and understanding of representations of the universe we could offer without it. (p. 121)

It will take some time to unpack this claim, but first a bit on the layout and intended audience of this book. The book consists of two parts: Part 1 is intended to provide a relatively self-contained presentation of the formal elements of QT.[1] After an interlude chapter summarizing problems with rival interpretations, Part 2 develops Healey's account further and draws out a variety of philosophical lessons about scientific representation, probability, explanation, meaning, and fundamentality, among other things. The book is primarily intended for those without a background in QT: philosophers, scientists, and laypeople interested in going beyond the metaphors found in popular presentations.

Healey's presentation in Part 1 is distinctive in a couple of respects. First, it introduces the mathematical formalism of QT by starting from detailed experimental procedures, going well beyond the simplified presentation of the two-slit and EPR experiments found in many philosophical treatments. Second, it is careful not to assume the usual representational role ascribed to parts of the formalism (especially, quantum states). It's hard to know whether these features will make the presentation more or less accessible to those without a background in the area; I suspect that for some philosophers the detailed presentations of experimental procedures and careful mathematical presentation will be tough going. That said, Healey has made an effort to make the material more accessible by relegating some of the details to appendixes at the back of the book and boxes in the text. For those with a familiarity of QT, Part 1 provides a careful and novel presentation of key notions. It also contains important details of the understanding of QT Healey advocates. Of particular importance is the treatment of the Born rule in Chapter 5, which Healey takes to apply to certain 'canonical magnitude claims' rather than to the outcomes of measurements. (I will return to this below.)

Roughly, the picture of QT introduced in Part 1 is as follows: The models used in QT are not straightforward representations or descriptions of physical reality, but rather are used to guide agents in their beliefs about certain non-quantum physical magnitude claims. For example, one might use QT to determine the probability of a silver atom hitting a screen at a certain location beyond a Stern–Gerlach apparatus. In the course of applying QT, one will assign a quantum state to the silver atom, but this quantum state is not a description of the physical condition of the atom. Rather, it—when combined with the Born rule—serves as a prescription of how one should set their credences about the location of impact on the screen.

At a first pass, Healey's view may draw comparisons to the Copenhagen interpretation, QBism, or simple instrumentalism, but there are important differences. First, while it doesn't function descriptively, the quantum state ascribed to some system is objective for Healey. For a given agent (hypothetical or actual), there is a correct quantum state to ascribe that is independent of the agent's subjective beliefs. Second, there is no important role played by measurements *per se*. QT tells an agent how to set her credences regarding some empirically significant canonical magnitude claim—something of the form $M_s \in \Delta$, where M is a dynamical variable of the system, s, whose value is in Δ. What counts as an empirically significant claim is determined by modelling the degree of environmentally induced decoherence associated with the quantum state of the system. For instance, a claim about the location of a silver atom after passing through a Stern–Gerlach apparatus (but before hitting the detection screen) lacks empirical significance so long as its quantum state has not decohered. Thus, QT provides no advice about such claims. However, once the atom impacts the detection screen, its interaction with the screen's constituents leads to rapid decoherence, and hence a claim about its location on the screen counts as a significant canonical magnitude claim.

Part 2 seeks to further develop the account and reveal its implications for a variety of philosophical topics. There are many interesting and controversial claims to be found here, but perhaps most important is the role of meaning, as this adds another dimension to Healey's view and further distinguishes it from simple instrumentalism. Given what's been said so far, the primary role for QT is to provide expert advice as to how agents should set their credences regarding significant canonical magnitude claims. While such magnitude claims needn't be measurement outcomes (most instances of decoherence occur outside of the lab), one still gets the feeling that QT functions as a kind of magic 8-ball, providing advice with no account of why it does so. The account of meaning proposed in Chapter 12 promises to say how QT influences our understanding of reality by altering the meaning of various claims describing it.

Return again to a sliver atom passing through a Stern–Gerlach device. One may make various claims about the atom and the apparatus without any use of QT; for example: 'The atom is emitted via a certain preparation procedure', 'The atom is detected by a screen'. If one were unaware of QT, they may draw certain inferences from these claims—for example, ‘the atom has a certain determinate value of angular momentum after passing through the apparatus’. On the inferentialist view of meaning (Brandom [1998], [2009]) endorsed by Healey, the meaning of such claims is constituted by their place in a web of inferences of this kind.[2] When we apply QT to a given situation, it alters the inferences we may draw from (and to) the canonical magnitude claims involved and hence changes their meaning. For instance, we cannot infer that an atom has a determinate angular momentum after passing through the Stern–Gerlach device because such claims lack empirical significance (and indeed, such inferences could get us into trouble if further experiments are performed on the atom). Thus, QT impacts our description of the world not by providing novel descriptions, but by altering the meaning of our non-quantum descriptions. This important second role for QT is not so easily dismissed as instrumentalism.[3]

To recap, Healey proposes two primary roles for QT: (1) to provide expert advice on how situated agents (real or hypothetical) should set their credences for significant canonical magnitude claims and (2) to affect the meaning of such claims by altering the web of inferences in which they occur.

Some will be unhappy with the understanding of QT offered in this book. Those who look to physics for a God’s-eye description of reality will be dissatisfied with Healey’s more modest claim that ‘by applying quantum theory we are able more effectively and responsibly to entertain significant claims about the world and to form reasonable expectations as to which are true’ (p. 237). In this way, QT only has an indirect influence on our understanding of the world. This prompts the question, where should we turn for a direct representation of reality?

This question faces any interpretation that rejects the assumption that quantum models represent (correspond to) aspects of reality. Some QBists seem to have retreated to the phenomenal realm and claimed that QT tells us only about what future experiences one should expect. The Copenhagen interpretation attempted to draw a bold line between the classical world of measurement apparatuses and the ineffable quantum reality we measure with these instruments. Healey wisely avoids the appeal to ‘classical’ description, noting that we sometimes apply QT to systems such as the Higgs field, or a K^0 meson with its quark constituents (p. 130). Instead, he proposes that QT requires certain ontological assumptions that he calls—in contrast to Bell’s term ‘beables’—assumables (p. 127). Thus, QT doesn’t have any ontology of its own (beables), but rather borrows ontology from elsewhere (assumables) in its application. But what is the source and status of assumables?

This question points to a certain tension in Healey’s view. On the one hand, QT is supposed to be a revelation, revealing ‘what philosophers should have known anyway’ (p. 203). On the other hand, QT is revolutionary in that its models serve their function without directly representing anything physical. The former idea would seem to motivate adopting a thoroughgoing pragmatism about science, one which disavows altogether scientific practices aimed at the faithful representation of a mind-independent reality. But the latter idea suggests that QT is unique in lacking beables of its own; presumably, other physical theories do directly represent the world. This hybrid picture seems to be suggested by the non-quantum canonical magnitude claims that QT tells us about. Both ideas face challenges: the hybrid approach requires saying why it is that QT is unique among physical theories in deploying non-representational models. The full pragmatist approach faces familiar worries about relativism, but also threatens to undermine much of the novelty of Healey’s account of QT. If all scientific theories are to be understood solely as useful guides for situated agents, then what sense can be made of the claim that quantum states do not function descriptively? They would seem to have the same status as states in classical physics: both feature in our best guides for navigating the world.

Another question concerns the kinds of explanations available on Healey’s view. Realists often object that non-descriptive understandings of QT undermine that theory’s ability to explain important physical phenomena.[4] Healey claims that his view allows for explanation by: (1) rendering the explanandum expected and (2) telling us what it depends on. For instance, in an EPR experiment, we can say that violations of Bell inequalities found when Alice and Bob compare their data are to be expected given the preparation procedure and the resultant Born probabilities. We can also say that the correlations in measurement outcomes counterfactually depend on the common preparation procedure. But there seems to be something missing from Healey's proposed explanation. As he notes: 'the theory has no resources to describe any causes mediating between [the preparation] and the recording events' (p. 183). For the traditional realist, there is a story to be told about the evolution of the system—corresponding to the evolution of its quantum state—but, for Healey, such a story is unavailable.

On Healey's view, quantum models act as 'informational bridges' between non-quantum magnitude claims without describing underlying physical processes involving the systems to which they are applied (p. 207; see also Healey [2017]). But some bridges are better than others, and we'd like an explanation for why this is so. Bridges that stand have features that bridges that fall down lack: they are based in true principles of engineering. Similarly, that our quantum models provide effective bridges stands in need of explanation if they are non-representational. One particularly striking case is environmental decoherence, which, as an evolution of quantum states, does not correspond to any physical process on Healey's view. But why should we care about whether decoherence occurs in a model? The answer that doing so is simply required by accepting QT strikes me as unsatisfying (p. 131). Normative prescriptions are only as good as their motivation, and descriptive explanations are an important source of such motivation.

In sum, while I have some reservations about Healey's pragmatist account, *The Quantum Revolution* marks a major advance. The vast majority of quantum interpreters have simply assumed that QT provides a novel description of reality. Those that have recognized other options typically have in mind subjectivist views like QBism. Healey's view provides an important third option: QT provides objectively correct guidance about the world. Healey's view suggests a radical revision to the standard problems and the philosophical import of QT, and such a shake-up is certainly good for progress in the area.

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Notes

[1] Healey uses 'quantum theory' rather than 'quantum mechanics' as his account is meant to apply not only to the non-relativistic quantum mechanics of particles, but also to quantum field theory and even proposed accounts of quantum gravity.

[2] These inferences are intended to be 'material' inferences (Sellars [1953]), which needn't be deductively valid.

[3] It does bear a similarity to Bohr's views, for example, that 'Physics concerns what we can say about nature' (see p. 253).

[4] See, for instance, the criticisms of QBism in (Timpson [2008]; Wallace [unpublished]; Brown [unpublished]).