

Naturalism and the interpretation of quantum mechanics

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Abstract

Quantum mechanics is the paradigmatic example of a scientific theory seemingly demanding ‘an interpretation’. Bas van Fraassen has recently argued that the attitude towards the task of interpreting science can be used to demarcate two otherwise similar epistemic stances: empiricism and naturalism. He claims that while empiricists are committed to the task of interpretation, naturalists do not have room to make sense of interpretation from outside the scientific theory. Naturalists, it seems, would have to be quietists about interpretation. I investigate in what form, if any, naturalists can make sense of the task of interpretation in the case of quantum mechanics. Doing so will shed light on the question whether interpretation of physical theories is a distinctively philosophical task, and what its purpose might be. I suggest that the aim of interpreting theories is to enhance our understanding, and that this task is not exclusively philosophical.

1 Introduction

Quantum mechanics is a theory notoriously ‘in need of an interpretation’. Providing and assessing such interpretations, of quantum mechanics and other physical theories, has become a central task of philosophy of physics. Being able to contribute to such interpretive endeavours would accordingly seem to be of great importance to philosophical naturalism, which places science at the heart of inquiry and views philosophy as continuous with science. Interpreting physics is commonly regarded as good strategy for arriving at a *naturalistic* ontology [Ladymann and Ross, 2007]. It is hence surprising that Bas van Fraassen has recently made the case that naturalists, unlike empiricists, are unable to make sense of interpretive tasks [2015]. Indeed, he claims that resistance to the project of interpreting science is a *characteristic* feature of philosophical naturalism. To make matters worse, van Fraassen further suggests that this refusal poses a problem for philosophical naturalism as a view of science, because the interpretation of scientific theories makes a key contribution to our understanding of these theories. If van Fraassen is right, then naturalism would seem to be a rather unattractive philosophical position vis-à-vis the sciences.

The question I will pursue in this chapter is whether there are interpretive

projects a naturalist might be able to engage with, and if so, whether these are of a sort that would permit naturalists to respond to van Fraassen's challenge. I will argue that naturalists can improve their understanding of scientific theories just like empiricists can, but that they will not do so by engaging in an explicitly extra-scientific or philosophical project of interpretation. The key difference between van Fraassen's empiricist interpreter and more naturalistic approaches is that naturalists take understanding, including explanatory understanding, to be an epistemic aim of science and scientific practice, whereas van Fraassen treats it as an aim of some further, philosophical activity.

For van Fraassen, to interpret a scientific theory is to ask, "under what circumstances is this theory true? What does it say the world is like?" [van Fraassen, 1991, 242] The model of interpretation he puts forward is that of interpreting a text and its relation to us and to the world; we improve our understanding of the text by offering a range of competing interpretations. While van Fraassen is right to point out that his kind of interpretive project is hard to make sense of from a naturalistic viewpoint, I will argue that naturalists can achieve understanding, including explanatory understanding, by means other than interpretation in the empiricist's sense. Naturalists and empiricists disagree over what it takes to offer an interpretation. Van Fraassen's argument hence succeeds as a diagnosis of the difference between empiricist and naturalist stances, but it is less compelling as a critique of naturalism, as it is unlikely to sway committed naturalists, who reject the idea that we need to engage in interpretation to achieve understanding.

The chapter is divided into three main parts. First, I present van Fraassen's challenge to naturalism, then I look closely at the case of quantum mechanics as a paradigmatic physical theory subject to diverse interpretive projects. Finally I show how the difference over interpretation between naturalists and empiricists results from a disagreement over what it takes to understand a scientific theory.

2 Van Fraassen's challenge

Some terminological housekeeping is in order to set the stage for van Fraassen's challenge. Both naturalism and empiricism will be treated as *stances*, not as theses. A stance, unlike a philosophical thesis or dogma, involves both belief-like elements, and non-belief elements.¹ Treating broad philosophical positions as stances is a way of acknowledging that there is no entirely neutral ground from which to evaluate philosophical positions and that there is an element of voluntarism in adopting or rejecting a particular such stance. Stances may be criticised, but such criticism will typically have to show how a stance fails by its own lights, not that it is incompatible with, or unattractive from, the point of view of a competing stance. Naturalism is further characterised by epistemic anti-foundationalism and fallibilism—any belief or theory is potentially subject

¹For more discussion of the notion of a stance see [van Fraassen, 2002] and [Rowbottom and Bueno, 2011]; for naturalism as a stance, see [Wolff, 2015].

to revision, and no source of beliefs or method of inquiry is regarded as incorrigible. Science plays a central role in this epistemic stance: our best current science provides the starting point for all inquiry, and is typically to be regarded as the only conceivable model for inquiry.

This form of naturalism has been developed especially clearly in Penelope Maddy's *Second Philosophy* [2007], where second philosophy is the activity of an idealised inquirer, the *Second Philosopher*. Unlike 'first philosophers', the second philosopher is deeply immersed in the practices of current science, and she approaches all questions, including in particular 'philosophical' questions, entirely 'from within' scientific inquiry. The second philosopher, as Maddy describes her, is "from birth" a busy sailor on Neurath's boat [Maddy, 2007, 85]. As a result of her position embedded within scientific practice, she rejects certain 'traditional' philosophical questions and projects as unintelligible or as of interest only from a perspective outside of science, which is a perspective the second philosopher does not adopt.

Van Fraassen is keen to distinguish empiricism from naturalism thus conceived, and he aims to show that naturalism is ultimately a problematic stance to take towards science. Empiricism is here also to be understood as a stance, as anti-foundationalist, and as a view that takes science to be central to inquiry. It is important for him, then, to distinguish empiricism from naturalism, and to show that empiricism is a more viable stance. Since both views are treated as stances, however, it is particularly important that naturalism must be shown to be unsuccessful by its own lights; it won't do to show that *from an empiricist point of view*, naturalism does not look attractive.

Van Fraassen sets up his challenge to Maddy's naturalism by drawing a distinction between the "naturalistic native", who is Maddy's ideal inquirer, and the naturalistic philosopher, who, like Maddy, offers up the naturalistic native as a paradigmatic participant of contemporary science. This distinction is important for van Fraassen, since he suggests that Maddy's strategy for rejecting certain types of questions relies crucially on sliding back-and-forth between the position of the naturalistic native and that of the naturalistic philosopher [van Fraassen, 2015, 69].

Van Fraassen grants naturalists of all stripes the right to adopt a particular epistemic stance towards science and taking it as a starting point for their mode of inquiry and philosophical outlook. Adopting such a stance is not a problem. What is a problem, however, is the manner in which naturalists seem to be in denial about taking a stance at all. Van Fraassen argues that to treat the naturalistic native as the paradigmatic participant in the scientific enterprise is to offer an interpretation of what science is. A problematic feature of naturalism is that this interpretative stance (often) remains unacknowledged as such; in particular, the possibility of alternative interpretations of what it means to be paradigmatic participant in science is denied or engagement with these alternatives is refused. Just as the naturalistic philosopher puts forward her naturalistic native as the paradigmatic practitioner in scientific practice, van Fraassen suggests, an empiricist or pragmatist might put forward different model inquirers [van Fraassen, 2015, 78]. Who one takes to be a model participant will

reflect what one takes to be the aims and methods of scientific inquiry. The conception of an ideal inquirer is not neutral between different philosophical stances one might take towards science. At the very least this non-neutrality needs to be acknowledged by the naturalists, even if one grants them the right to take such a stance without first offering a stance-independent defence for it, as van Fraassen does.²

Instead, Maddy and other naturalistic philosophers seem to refrain from defending their take on science against possible alternatives. Maddy's criticism of "first philosophy" (which includes a wide range of viewpoints, including van Fraassen's empiricism) typically takes the form of rejecting the philosophical concerns that motivate these alternative views of science from the perspective of the "Second Philosopher". The second philosopher, Maddy argues, sees no need for a philosophical stepping back from scientific practice, and she struggles to understand what might possibly motivate others to take such a step [Maddy, 2007, e.g. 308-9]. From the empiricist perspective, however, this refusal to engage philosophical questions already betrays a particular outlook on science.

[T]he fundamental Naturalistic impulse is not so much to take science for granted as to take for granted a particular but unacknowledged philosophical view of what science is. Precisely if that is the case, the stance is not taken consciously and explicitly, but seen as unavoidable or inherent in what it is to be scientific at all. [van Fraassen, 2015, 80]

Failure to acknowledge one's own position as a stance is to fail to acknowledge that a choice was involved in adopting it, and that other choices are possible.

Could the naturalist simply respond by acknowledging that she has taken a stance? The cost of doing so would be to admit van Fraassen's distinction between the naturalistic native as the ideal scientific practitioner, and the naturalistic philosopher as the philosopher who puts forward the naturalistic native as an ideal participant in the first place. The second philosopher, as conceived of by Maddy, is both a paradigmatic practitioner in scientific practice, *and* a plausible candidate for a successful philosopher. But while the paradigmatic practitioner in scientific practice may indeed be oblivious to certain kinds of philosophical questions, it is implausible for a philosopher to fail to understand such questions, precisely because she needs to acknowledge that her view is one stance among several others. In failing to acknowledge her stance as a stance, the naturalist philosopher is failing as a philosopher, even though the naturalistic native could perhaps carry on with her practice without taking any philosophical stance at all.

A further problem van Fraassen raises for naturalism indirectly addresses this response. The naturalistic native, van Fraassen argues, is not only just one among several candidates for the paradigmatic participant in science; as portrayed by the naturalists, she is not even a particularly plausible one. In order to refuse engagement with alternative views, the second philosopher adopts the

²Granting this right is part of van Fraassen's stance voluntarism [van Fraassen, 2002].

outlook of the naturalistic native. The naturalistic native is unable and unwilling to take an interpretative stance towards her own scientific practice. Yet the history of science suggests that even within science, there are situations in which scientists need to be able to ‘step back’ from the practice at hand and reflect on the aims, methods, and content of the science they usually engage in. So the naturalistic native, as a paradigmatic participant in science, cannot be as oblivious to interpretation as the naturalistic philosopher makes her out to be, or she will fail in such situations.

The types of situations van Fraassen seems to have in mind are cases of Kuhnian ‘crisis science’—situations in which established methods and theories fail, and practitioners are forced to step back from the practice at hand to reflect on their presuppositions, aims, and methods. A paradigmatic case of such a situation is the development of quantum mechanics, where the need to interpret the newly developing theory became especially clear. If the naturalistic native is indeed unable to engage in such reflective and interpretive endeavours, she cannot be regarded as the paradigmatic participant, as she will be unable to handle situations of crisis. To handle such situations, van Fraassen suggests, she would have to be able to engage in a stepping back of just the sort the second philosopher earlier claimed was so alien to the naturalistic native that the questions and concerns raised by typical philosophers were unintelligible. Van Fraassen hence poses a dilemma for naturalists: “(a) to be in a position to share a point of view from which the sciences can be discussed, bracketing our beliefs about to what extent they are true, or (b) to be in no position even to survive as a Naturalistic Native in times of trouble” [van Fraassen, 2015, 85].

The dilemma hinges crucially on the claim that there are situations in which practicing scientists must be able to step back from their work and reflect critically on it *in the same manner* that would also force the naturalistic philosopher to reflect critically on her stance towards science and on the naturalistic native as a paradigmatic inquirer. I will come back to this distinction below when discussing understanding, but first let’s turn to our paradigmatic example, the case of quantum mechanics.

3 The case of quantum mechanics

QM is a paradigmatic case of science itself demanding an interpretation, both because when it was first developed, physics was ‘in trouble’ in the sense of a Kuhnian ‘crisis’, but more importantly because the theory as developed seemed difficult to understand. Unsurprisingly, van Fraassen chooses quantum mechanics as his example when he insists that theories are open to interpretation, and that a failure to engage in such interpretation is therefore a failure not just of the naturalistic philosopher, but of the naturalistic native as a paradigmatic participant of science.

Theories are formulated, their formulation is investigated in the context of the alternatives that are open: for example, quantum

mechanics is understood better now that we have seen Bohmian mechanics and the GRW theory. We could see all three, and compare them, discuss agreements and possible disparities in the empirical predictions, try to imagine at least thought experiments in which their differences would become manifest... We could much more clearly, because of the displayed contrasts, address the question what the world could possibly be like if it were as quantum mechanics says it is. What could I call this except a ‘level of analysis above that of science’? [van Fraassen, 2015, 83].

Van Fraassen here connects three ideas: (i) that greater understanding of quantum mechanics was achieved through the development and investigation of alternatives, (ii) that this investigation allowed us to address the interpretive question of ‘what the world could possibly be like if it were as quantum mechanics says it is’, and (iii) that interpreting theories in this sense involves stepping outside of science proper. The reason for this last step is that van Fraassen claims that to investigate alternatives requires treating our best science as open to re-interpretation; it requires bracketing what we think we know [van Fraassen, 2015, 84]. In calling this interpretive endeavour a ‘level of analysis above that of science’, van Fraassen poses a challenge to the naturalist: if her naturalistic native is unable to engage in interpretation, she has to give up on understanding (or on improving her understanding) of the scientific theories she takes for granted; but if she can and does engage in such interpretations, even the naturalistic native is engaged in stepping back from science, and there is hence no reason for the naturalistic philosopher to refuse to do so as well. We are right at the dilemma set out above.

A naturalist might wish to respond to this challenge by questioning, on the one hand, whether the interpretive activities described require a level of analysis above that science, and on the other hand the move from offering interpretations of particular scientific theories to taking an interpretative stance towards science as a whole. Both points make interpretation out to be distinctively *philosophical* in character, whereas the naturalist might want to suggest that there are forms of interpretation and understanding that are not beyond the native’s reach. Indeed, there seem to be three different moments of interpretation arising in connection with quantum mechanics: interpretive questions in the development of quantum mechanics, the development of alternative viewpoints in competition with ‘orthodox quantum mechanics’³, and finally the project of articulating what the world is like if quantum mechanics is true. When van Fraassen speaks of interpretation, he primarily has in mind this last project. It will nonetheless be worthwhile to talk about all three forms of interpretation, since what counts as an interpretation and what counts as understanding gained through the project of interpretation are not neutral ground between empiricists and naturalists. I now turn to these three interpretive projects, beginning with the initial development of quantum mechanics.

³The term ‘orthodox quantum mechanics’ is itself problematic; for discussion see [Wallace, 2016].

3.1 The development of quantum mechanics

The development of quantum mechanics is notorious as a tumultuous and exciting period in the history of science [Beller, 1999], and it is clearly a case where questions of interpretation arise from within science. On the one hand, a new theory was needed to make sense of a range of experimental results and effects, and on the other hand, newly developed approaches needed to be compared, assessed, and understood. Can naturalists make sense of these debates? Responding to empirical data by developing new bits of theory, comparing and evaluating potentially competing theoretical proposals, and deriving new empirical predictions from the proposals under discussion is all part and parcel of what it means to engage in science. Even in the especially excited debates over quantum mechanics, many of the activities in question simply look like (theoretical) physics and the debates are just what one might expect at the cutting edge of research.

It is nonetheless fair to describe these debates as involving interpretive questions. To acknowledge the mismatch between extant theory and experimental phenomena, and more specifically, to assess this mismatch as so significant as to warrant the development of an entirely new theory, requires entertaining the possibility that the theory that served as a starting point is not entirely true or possibly false altogether. That is to say, acknowledging that a scientific paradigm is in crisis requires stepping back from it to some extent. Moreover, once a new candidate has been proposed, it too seems to require interpretation: its concepts and principles are unfamiliar, and its relation to existing theories needs to be clarified. This was of course especially true for quantum mechanics, with the measurement problem, superpositions, and non-locality posing particular challenges.

It is correct, then, that science itself gives rise to interpretive questions of some sort, and that a good scientist needs to be able to respond to such situations of crisis. But this alone does not yet show that an appropriate response requires explicitly philosophical reflection, or rising ‘above’ the normal practice of science. Debates over interpretation were vivid, precisely because there was a plurality of viewpoints among scientists. It doesn’t seem as though we need to describe these debates as involving active ‘bracketing’ of what particular individuals took to be true, nor did it involve stepping back to a different, non-scientific activity altogether. Far from being bracketed, the different theoretical proposals were vehemently defended. The appeal to thought experiments or methodological principles in the course of these debates should not distract us from the fact that the ultimate goal was to develop an adequate physical theory, not a metaphysical world-view.

We should also note that the (re-)solution of these disputes was not a unified metaphysical picture of the world according to quantum mechanics. Instead we find a package of technical solutions, the consolidation of results, and a redirection of physics away from foundational disputes towards the development of quantum field theory and applications of quantum mechanics. It is also clear that philosophers do not think that the debate over the interpretation of

quantum mechanics was resolved at this point, and of course difficulties, like the relationship of classical to quantum mechanics remained unresolved [Bokulich, 2008]. We need to acknowledge, however, that closing off further interpretive questions helped physics to move beyond the state of crisis science and to return to normal science under a new paradigm. Not only do scientists need to be able to respond to crisis by stepping back from their beliefs and practices, as van Fraassen rightly observes; they conversely also need to be able close debate after a new theory emerges. The question, to which we shall return below, is whether naturalists have to side with the scientists who closed off these further questions, or whether they can engage with interpretive questions that arise even after the new paradigm has been established.

3.2 The development of alternative theories

A more serious challenge arises for naturalism with respect to theories like Bohmian mechanics and GRW (after the developers Ghirardi, Rimini, and Weber [Ghirardi et al., 1986]). Bohmian mechanics is a form of non-local hidden variables theory of quantum mechanics, whereas GRW offers a spontaneous collapse theory. Both views were primarily developed after the initial consolidation of quantum mechanics, and they were offered as alternatives to orthodox quantum mechanics.⁴ Van Fraassen moreover points to these two views in particular as interpretations that aided the understanding of quantum mechanics. What motivations might naturalistic natives have to engage with either of these viewpoints?

On behalf of the naturalist one might say that both Bohmian mechanics and GRW are in the first instance alternative physical theories, not (philosophical) interpretations of theories. Just like naturalistic natives could engage in the development of a brand new theory, we should expect them to be able to develop and assess possible rival theories even where one theory is already established. While doing so requires the ability to step-back from a particular set of beliefs, it doesn't require stepping outside the framework of science altogether.

The question whether Bohmian mechanics and GRW are alternative theories or interpretations of quantum mechanics is contested. Van Fraassen offers the following distinction [van Fraassen, 1991, 9]: an extension of a theory offers new empirical predictions, whereas an interpretation of an extant theory preserves all the predictions of the theory, and does not add any additional predictions. Since both Bohmian mechanics and GRW are developed (in the first instance) to match standard quantum mechanics in the realm of phenomena for which quantum mechanics was first developed, they would seem more like interpretations than like rival theories.

On the other hand, the Bohmian formalism differs from standard approaches to quantum mechanics. Some versions of Bohmian mechanics, for example, treat the Born rule as a theorem, not as an independent postulate [Dürr et al., 1992]

⁴The origins of Bohmian mechanics date back to [de Broglie, 1928], but the versions currently discussed as competitors to orthodox quantum mechanics were developed later.

[Valentini, 1991]. Moreover, it is not clear what a Bohmian version of quantum field theory might look like [Dürr et al., 2004]. So the theory differs both in the role played by certain propositions, and its relation to other theories. Those are relevant theoretical differences, even if no new empirical predictions were forthcoming.⁵ Indeed, the apparent lack of prospects for a Bohmian quantum field theory provides a strong reason for physicists to remain skeptical about Bohmian views and a disincentive to take the theory seriously as a rival to quantum mechanics.

Similarly, GRW is an extension of sorts, since it aims to offer a unified dynamics for microscopic and macroscopic systems. Like Bohmian mechanics, it is offered as a theoretical improvement over standard quantum mechanics. Where Bohmian mechanics seeks to improve upon ‘orthodox’ quantum mechanics by offering a deterministic theory that permits (some forms of) causal explanation, GRW aims to address the ‘measurement problem’ by offering a dynamics that does not single out measurement processes as primitive elements of the theory.

Neither theory, then, is an extension in the sense of (primarily) offering up new testable empirical hypotheses, but each can nonetheless be viewed as a new theoretical development in physics of some sort. To make matters even more complicated, not only were Bohmian mechanics and GRW themselves motivated by dissatisfaction with the orthodox interpretation of quantum mechanics, there now also exist further competing ‘interpretations’ of both Bohmian mechanics and GRW (e.g. [Allori, 2013], [Suárez, 2015], [Egg and Esfeld, 2015]). These interpretations are usually interpretations in the third sense (discussed below): they are attempts to find metaphysically palatable ontologies for Bohmian mechanics and GRW respectively. It seems that in whatever sense either Bohmian mechanics or GRW is to count as an interpretation of quantum mechanics, there is also a sense in which they are themselves theories open for interpretation. The distinction between a rival theory or an interpretation of an existing theory does not seem to be clear-cut in these cases, then. I shall argue below that whether these alternatives should be viewed as interpretations or as rival theories depends on how we think understanding of scientific theories can be achieved.

Whether naturalists can plausibly engage with either Bohmian mechanics or GRW depends heavily on how we think these views should be evaluated. If we take them to be interpretations, rather than rival theories, then their evaluation would seem to be a matter of extra-scientific considerations, and hence not something a naturalist can easily engage with. If they are rival views or theoretical developments of an existing theory, on the other hand, they will be evaluated along the same lines as other scientific theories, and insofar as natu-

⁵The extent to which the theories make differing predictions is controversial; if we include the differences in compatibility with relativistic settings among the empirical differences, then both GRW and Bohmian mechanics do differ empirically from orthodox quantum mechanics. I’m willing to restrict the empirical differences to the original domain of quantum mechanics, where GRW and Bohmian mechanics aim to match the predictions of orthodox quantum mechanics. If we were to include them as empirical differences, then the naturalist’s suggestion that these are just different physical theories would seem to be even more convincing.

realists are not bound to adhere strictly to the theories they ‘grew up with’, they can certainly entertain and evaluate competing proposals on the same standards they apply to all scientific theories. Unlike the debates during the development of quantum mechanics, engagement with rival views to extant theories requires a certain amount of ‘stepping back’ from the currently accepted theory. But what needs stepping back from here is not science as a whole, but only a subset of beliefs in a particular field. Naturalists may be dogmatic about their stance towards science, but that does not mean they also have to be dogmatic about any particular scientific theory.

3.3 The ontology of theories

The third project of interpreting quantum mechanics looks more distinctively philosophical: it is to provide a kind of fleshed-out metaphysical picture of what the world would have to be like, if quantum mechanics were indeed true. This is of course the sense of interpretation van Fraassen has in mind, first and foremost. It is this project that both empiricists and realists can engage in when it comes to scientific theories, because both take the semantics of science to be broadly realist—they differ merely in their epistemic attitude towards the theories in question [van Fraassen, 1991, 4].

Since this project explicitly addresses theory–world relations, it poses the most severe difficulties for the naturalistic native. The naturalistic native is happy to ask whether the evidence speaks in favour of any one of several hypotheses, but questions about how theories in general relate to the world, or what overall ontology a theory suggests, are precisely the sorts of questions she wants to resist. Just as she doesn’t understand the (on her view) skeptical perspective offered by empiricism, she equally doesn’t understand the realists’ ‘footstamp’.⁶ To her, the latter does not add anything over and above the evidence available from within science, and it is on the basis of this evidence, not on account of any global attitude towards science, that she is able and willing to engage ontological questions at all. Maddy suggests that the second philosopher can ask “what does this [successful bit of science] tell us about how the world is?” [Maddy, 2007, 397]. But for the second philosopher, the answer to this question will typically be straightforward, with allowances for anything resembling ‘interpretation’ made only for idealisation and mathematisation. For Maddy’s second philosopher, there is no *general* problem of how to understand scientific theories, nor is there a general, extra-scientific criterion for what there is, or even for what there is according to a particular theory. Instead there will be a long list of particular answers to particular existence questions, based not on ‘what science tells us there is’, but based on the strength of the evidence offered up for the existence of the putative entities in question [Maddy, 2007, 397].

The second philosopher believes that particles like electrons exist on the basis of scientific evidence, not because she is in general committed to believing

⁶For a detailed account of the relationship between Maddy’s naturalism and scientific realism, see [Wolff, 2015].

in the entities ‘our best science’ says there are. Upon inspection she might, for example, decide to withhold belief in Higgs-Bosons, if she finds the LHC results insufficient. At the same time she is unlikely to demand interpretation or ontology beyond what is currently offered by the relevant scientific theories. If quantum mechanics suggests that electrons are particles, but that particles do not follow determinate trajectories, and she is persuaded by the evidence in favour of quantum mechanics, then this is the view of particles the second philosopher will adopt, without insisting that to have a proper interpretation or ontology for the theory, we need something else in addition. With this piecemeal approach in mind, it is hard to see how she can find questions as to whether the ontology of quantum theory involves particles (and particles only) in its (primitive) ontology, worth engaging. Similarly, she will be puzzled by questions as to what the ontological status of the wave-function, or whether quantum mechanics requires a holism incompatible with Humean metaphysics. These do seem like extra scientific considerations and questions. They also seem like considerations that may ultimately rely on different views of science or different background metaphysical commitments, neither of which the naturalistic native is supposed to have. So it seems van Fraassen is right to suggest that this is an interpretative enterprise the naturalistic native will likely reject.

Rejecting the interpretive project as van Fraassen understands it does not by itself pose a problem for naturalism. It is a problem for naturalism only insofar as the benefit derived from interpreting theories is not otherwise available to naturalists and insofar as these benefits are worth having. Since the main purpose or aim of interpretation is greater understanding of scientific theories, we need to ask what kind of understanding one might hope to obtain from the kind of interpretive projects described here. If there is understanding to be gained, and gained only by way of finding ‘the ontology’ of a given theory, and this understanding is arguably an aim of science, then the naturalistic native will indeed fall short of being a model participant in the scientific enterprise. For then there would be a cognitive achievement not available to her, but available under a competing conception of what it means to be a model participant. On the other hand, if there is no such understanding forthcoming, or if such understanding is not within the remit of science, then it seems the naturalistic native is not losing out by failing to engage in this form of interpretation and can hence not be said to fail by her own lights (or by the lights of the naturalistic philosopher, who offers the native as a stand-in).

4 Interpretation and Understanding

4.1 Understanding theories

The main purpose of interpreting theories was to increase our understanding of them. We should ask, then, whether naturalists can achieve understanding without engaging in explicitly interpretative projects of the third type, or whether they might have reasons to reject the understanding allegedly provided

by such projects as spurious. What do we mean by ‘understanding’?

While there is no unique way of classifying understanding, a commonly drawn distinction is between symbolic, objectual, and explanatory understanding [Baumberger et al., 2017, 4]. The first refers to understanding in the sense of understanding a language, or more broadly a type of symbolic representation; the second means understanding a particular domain or subject matter, and the third is to understand why something is the case. The relationship between these different forms of understanding is somewhat controversial, but at least prima facie they are quite different. The question is therefore, which forms of understanding naturalists might aim for, and how they might do so.

Since quantum mechanics is in the first instance treated as a mathematical formalism, understanding quantum mechanics seems to require symbolic understanding [Baumberger et al., 2017]. It seems fair to say that the symbolic understanding of quantum mechanics has increased since its first inception in Heisenberg’s and Schrödinger’s seminal work. All three forms of understanding were initially absent, which perhaps explains the sense of crisis and the intense engagement in interpretation in the early days of quantum mechanics. Once Heisenberg’s and Schrödinger’s formulations had been shown to be equivalent, a passable level of symbolic understanding had been achieved and the standardisation of presentations of quantum mechanics using Hilbert spaces helped to spread a unified understanding of quantum mechanics as a formalism.

After such symbolic understanding had been achieved, it became possible to reject other interpretive projects as superfluous; it was now possible to calculate, and hence possible to ‘shut up’ about other forms of understanding one might hope to achieve. The attitude many physicists adopted in this period was to accept symbolic understanding as the only understanding necessary for doing physics, and to reject the demands for other forms of understanding as not within the remit of physics. If physics only provides symbolic understanding, then any questions aimed at explanatory understanding are left unanswered. With this sharp division between mere symbolic understanding as the only task of physics and all other forms of understanding relegated to ‘mere’ philosophising, van Fraassen’s suggestion that interpretation involves analysis at a level beyond science seems quite plausible. If all the scientific work is done once a working formalism has been established, then any engagement with questions that aim at explanatory understanding will seem beyond the remit of science proper. Interpretation of theories would then indeed seem like a separate, extra-scientific enterprise, just like van Fraassen suggests.

Accordingly van Fraassen sometimes seems to think of the naturalistic native as a scientist who only aims for symbolic understanding, and who, in virtue of being a ‘native speaker’ of the language of the theory, cannot even comprehend what it would mean to treat the theory as open to interpretation [van Fraassen, 2015, 82]. If this is the right way to think of the naturalistic native, naturalists would lose out on a form of understanding ostensibly provided by interpreting scientific theories: explanatory understanding. Naturalists might want to reject the claim that such interpretations provide any genuine or useful understanding at all, but to do so requires an independent argument and it is not clear that

such an argument can be given. So we might agree with van Fraassen that naturalists would be missing something. Van Fraassen’s likens this type of naturalistic native to a fundamentalist about scripture [van Fraassen, 2015, 82]. For a fundamentalist about scripture understanding doesn’t go beyond faithful recitation of words on the page, and any doubts or questions about the ‘text’, in this case, about orthodox quantum mechanics, are suppressed and extinguished. In particular, a fundamentalist can neither ask how we relate to the ‘text’ or how the ‘text’ relates to the world. Even asking for a different kind of understanding is to be made illegal. A fundamentalist literalist of this type will not strike most philosophers as the ideal participant in scientific inquiry, and would indeed seem lost in situations of scientific crisis.

A naturalist, who is already committed to the view that science and philosophy are continuous, might take a different stance. She might suggest instead that explanatory understanding was simply unavailable at the time and that scientific methods were insufficient to choose a more specific theory—one that settled certain explanatory questions—based on the evidence available. So it was reasonable in that context to continue work based on a purely symbolic understanding, bracketing all questions of explanation. She might nonetheless suggest that explanation is in principle an epistemic aim of science, and that providing explanatory understanding is a distinct virtue of a scientific theory. That is to say, she might accept that historically ‘shut-up-and-calculate’ was the right strategy, while acknowledging that explanatory understanding is still missing. Unlike van Fraassen’s empiricist, and unlike the shut-up and calculate physicist, however, she does take such understanding to be an aim of future science. If so, naturalists may not have to forgo explanatory understanding altogether, but will have to achieve it by means other than interpretation in van Fraassen’s sense.

The contextualist approach to explanatory understanding suggested by de Regt and Dieks [2005] is particularly helpful for developing this naturalistic response. They suggest that explanatory understanding is *contextual* in the sense that what particular features of a theory are considered explanatory is highly sensitive to historical context. They show, for example, that whether a mechanistic explanation or an explanation involving action-at-a-distance forces counts as a paradigmatic case of an explanatory theory is highly dependent on the historical context. Crucially de Regt and Dieks insist that understanding, including explanatory understanding, is a central aim of science itself, despite its pragmatic character. On their view, “A scientific theory T is intelligible for scientists (in context C) if they can recognise qualitatively characteristic consequences of T without performing exact calculations” [de Regt and Dieks, 2005, 151].⁷ This definition acknowledges the pragmatic and contextual features of intelligibility, while at the same time offering a substantive criterion for it. A scientist understands a theory when she has a sense of what the theory says

⁷De Regt and Dieks apply the term ‘understanding’ to our attitude towards a particular phenomenon; we understand a phenomenon when we have an intelligible theory of it [de Regt and Dieks, 2005, 150]. Understanding of a domain or phenomenon is hence gained by developing an intelligible (or more intelligible) theory of the domain.

will happen qualitatively, independently of carrying out detailed calculations. This is a plausible criterion,⁸ which, as they show, applies to a wide range of more specific criteria for intelligibility, like visualisability or causal-mechanical models, which were relevant in particular historical contexts.

Naturalists will find the contextual approach to explanatory understanding congenial: it does justice to the wide range of demands for understanding that are made of scientific theories, and it does particularly well in cases like quantum mechanics, where not just one, but multiple standards for understanding were invoked to evaluate the different proposals. Quantum mechanics posed a challenge to understanding in numerous ways: the lack of anything like a causal-mechanical story, non-locality, and surprising principles like the uncertainty relation and superposition. Unsurprisingly, then, orthodox quantum mechanics has not been treated as an intelligible theory in the sense given by de Regt and Dieks. It is possible to make very accurate predictions using the quantum formalism, but it is very difficult to provide anything like a qualitative account of what is going on.

Bohmian mechanics, and to a lesser degree GRW, can be seen as later attempts to improve upon orthodox quantum mechanics, precisely by offering *explanatory understanding* in addition to merely symbolic understanding of an empirically successful theory. Both theories are supposed to be more intelligible than orthodox quantum mechanics, albeit in different ways. In the context of ‘shut-up-and-calculate’, explanatory understanding is regarded as a purely philosophical goal, and hence these views continue to be regarded, both by physicists and philosophers, as being ‘philosophically’ motivated. But the allocation of labour here is secondary; the more important point is that these theories aim to do better than quantum mechanics by offering explanatory understanding in addition to empirically adequate predictions. For a naturalist not trapped in the shut-up-and-calculate paradigm, this means that these theories can be evaluated according to their overall virtues. Since they are meant to be effectively empirically equivalent to quantum mechanics, a naturalist will turn to non-empirical virtues to choose between them. Intelligibility, however it may be cashed out in a given context, will be among such virtues for the naturalist. But there are others to be considered as well: simplicity and fruitfulness, for instance. It is with respect to fruitfulness that Bohmian mechanics falls short in the eyes of many physicists. Crucially, these virtues will be treated as *epistemic* reasons for accepting the theory, not merely as pragmatic reasons.

Now it begins to look as though naturalists might have a route to understanding that does not involve interpretation of scientific theories ‘from the outside’, as it were. Assessing what is gained by accepting a more intelligible theory is traded off against the fruitfulness or simplicity of the theory. These decisions involve pragmatic elements, but they are not *merely* pragmatic and are taken by the naturalist as being a normal part of what scientists do when developing and assessing new theories. This naturalistic response seems a lot

⁸De Regt and Dieks trace back versions of this criterion to Heisenberg and Feynman [de Regt and Dieks, 2005, 151].

more attractive than the dismissive attitude towards explanatory understanding seemingly displayed by the naturalistic native understood as a follower of shut-up-and-calculate. For the naturalist, there will be no sharp distinction between a theory and its interpretation, and no division of labour between developing a fruitful theory and an intelligible one.⁹

This does not mean that naturalists will engage in exactly the same questions as the philosophers who offer interpretations of physical theories. Merely offering an ontology for a theory, or arguing that a particular theory is or isn't compatible with a preferred metaphysical outlook, does not by itself enhance the intelligibility of the theory. It might contribute to it, though, if by providing an ontology the theory becomes intelligible to scientists, that is, if it makes it possible for scientists to offer qualitative, non-calculative predictions. Perhaps we should then think of the naturalistic native not as rejecting all forms of understanding besides symbolic understanding as outside the scope of science, but instead as somebody who takes explanatory understanding as an epistemic aim of science and who hence treats intelligibility as an epistemic virtue of a theory. This contrasts of course with van Fraassen's view [van Fraassen, 1980], who suggests that explanation, and hence presumably also explanatory understanding, are too pragmatic to be properly among the epistemic goals of science.¹⁰ And it is here, perhaps, that we find the real difference between naturalism and empiricism when it comes to the interpretation of theories.

4.2 Interpreting science

Naturalists, then, can aim to understand scientific theories, even if they do so not by means of extra-scientific interpretations. There was another interpretive project van Fraassen was asking naturalists to engage in, namely the project of taking a stance towards science as an activity: "an interpretive stance is open to us and indeed, is *needed* to understand our own situation properly" [van Fraassen, 2015, 85]. Whereas the former project was aimed at understanding a particular scientific theory, the latter is aimed at understanding our relationship to particular theories and, more importantly, to science as a practice or activity. 'Our situation' here would seem to mean the human condition as a whole, not just the particular qualitative picture appropriate for quantum mechanics. Nothing in what I've said so far shows how a naturalist can engage in this second project of interpretation. One reason for this might be that the two projects, *pace* van Fraassen, can come apart. A theory can be intelligible to a scientist, and hence confer understanding of a phenomenon in the sense of de Regt and Dieks, even while the same scientist is not particularly reflective of her engagement in scientific practice. As *philosophers*, by contrast, we indeed often aim for understanding not only of a particular phenomenon, but of entire

⁹Maddy seems to agree; she approvingly cites Marc Lang's rejection of a sharp division between theory and interpretation [Lange, 2002, 250] cf. [Maddy, 2007, 409].

¹⁰Compare also: "The reason they [questions of interpretation] are often difficult to answer is, in my opinion, that scientific discussion is so thoroughly focused on the question of empirical adequacy alone" [van Fraassen, 1991, 242].

practices, like science. What seems puzzling about Maddy's second philosopher is indeed how uninterested she seems to be in questions aimed at this second interpretive project, but that doesn't mean her portrait of the ideal inquirer is inadequate as a portrayal of the model empirical scientist. If second philosophy is dissatisfying as a philosophical stance, it is not dissatisfying because of its view of science and its aims, but because of its view of philosophy and its aims. To say so will not do as an *argument* against naturalism as a stance, since it would beg the question against the key naturalistic commitment—that philosophy is continuous with science—but it helps to explain the dissatisfaction non-naturalists have with that stance.

5 Conclusion

I've argued that while van Fraassen is right to point out that under a certain conception of what it means to interpret a theory, naturalists will not be able to engage in such a project, this does not pose as grave of a problem to naturalism as van Fraassen makes out to be. The aim of such interpretations is to improve our understanding of these theories and the phenomena they describe, which is something naturalists will perceive as an epistemic aim of science, and hence within reach of the normal methods of proposing and evaluating scientific theories. Since this form of understanding can be achieved by means other than philosophical interpretation, naturalists can escape van Fraassen's dilemma. The naturalistic native is in a position to respond to crisis science and she can evaluate proposals with a view to their potential for increasing understanding. Unlike the empiricist, she will do so as part of assessing the prospects of such proposals as physical theories, taking into account intelligibility among other non-empirical virtues a theory might possess, and trading them off against one another. This does not mean that she will be rationally compelled to a single answer in all cases, but it also doesn't mean that she needs to engage in a further interpretive project of asking what stance we should take towards scientific theories in general. This question is quite distinct from the project of improving our understanding of particular theories, about which naturalists need not be quietists. More broadly, I've suggested that the aim of interpreting theories is to improve our understanding. Doing so will go beyond merely symbolic understanding, but it seems perfectly possible to engage in some interpretive projects—the exploration of variants and alternatives to the standard theory—while declining to engage in others, e.g., providing a full metaphysical picture of what the world is like according to quantum mechanics.

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