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Abduction and the Scientific Realist Case for Properties

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Abstract

Traditionally, many arguments for realism about properties (universals or tropes) rely on *a priori* claims. The author argues that if we make use of an abductive principle that is commonly employed by scientific realists, a new argument for property realism can be formulated which is based firmly in scientific practice. The abductive principle says that we should believe in the existence of certain theoretical entities if they figure in the best explanation for what scientists observe. The scientific argument for property realism then says (roughly) that the best explanation for various behavioural patterns that physical scientists observe is that microscopic entities (such as electrons) instantiate stable, causally efficacious properties. After presenting the argument, the author defends it against possible objections. More generally, the article provides a case study for how science and metaphysics can work together to generate ontological claims.

Keywords

scientific realism – properties – causation – abduction – inference to the best explanation

1 Introduction: Scientific Realism, Scientific Properties and Abduction

Scientific realists believe in the mind-independent existence of many of the unobservables that we find in scientific theory. A common argument for this view, and perhaps the *central* argument for this view, relies on an abductive principle, which says that we should believe in the existence of an entity, or

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type of entity, if it figures in the *best explanation* for the observable phenomena. With this principle in place, the scientific realists argue that various theoretical entities do indeed figure in the best explanation for the phenomena observed by scientists. In particular, scientific realists tend to posit the existence of physical entities. For instance, it is argued that we are entitled to believe in the existence of particles like electrons and quarks because the existence of such particles provides the best explanation for the fact that, in certain experimental contexts, the observable world behaves *as if* particles exist. Those who abductively infer the mind-independent existence of physical entities like particles are what Brian Ellis calls 'scientific entity realists', and its proponents include Smart (1963), Cartwright (1983), Devitt (1997) and Ellis himself (1987). Devitt (1997, 108) summarises the approach as follows:

> The basic argument for the unobservable entities is simple. By supposing they exist, we can give good explanations of the behaviour and characteristics of observed entities, behaviour and characteristics which would otherwise remain completely inexplicable.

Now, what is interesting to note is that an ontological commitment to the entities posited by scientific realists, such as particles, does not automatically commit us to the fundamental existence of the properties had by those entities. We might say, for example, that a particle has properties like mass, charge, spin and so on, but the particle is not itself a property and it is an open question as to whether the property ascriptions carry ontological commitment. Using terminology from classical metaphysics, we might say that scientific entity realists are realists about various *substances*.[1] But as Ellis notes (1987, 50), one wonders whether the scientific realists' abductive strategy could or should be applied to entities falling in other metaphysical categories, such as the theoretical properties described above. Consider again the Devitt quotation above (1997, 108). If we replace 'unobservable entities' with 'unobservable properties', perhaps we are left with a sketch of a promising science-based argument for property realism: *the basic argument for the unobservable properties is simple. By supposing they exist, we can give good explanations of the behaviour and characteristics of observed entities, behaviour and characteristics which would otherwise remain completely inexplicable*. Of course, in order to make such an argument we would still need a realist commitment to the entity

1 I use the term 'substance' in a flexible way. I don't mean to imply, for example, that scientific entity realists are committed to an Aristotelian theory of substance or a Lockean theory of unknowable substance.

realists' physical substances, because it would be odd to be a realist about properties but not a realist about the bearers of those properties. However, the idea behind the abductive argument for scientific properties would be that to provide a good explanation for the full range of observable phenomena, we need to posit real properties as well as the bearers of those properties. Otherwise, it is difficult to see how entities like electrons can deliver explanations in the way that entity realists suggest (more on this later). Such an argument would also provide a weapon against nominalist approaches to properties, which do not take properties to be ontologically fundamental, and would open the way for a robust realism about scientific theoretical properties.

The aim of this article is to explore how one might develop this abductive argument for realism about theoretical properties, such as charge, mass and spin. Since the role of these properties will be to help to causally explain various behavioural patterns that we observe in science, they are what I shall call *causally efficacious* properties: properties which play specific causal roles.[2] If a promising science-based abductive argument for such properties can be developed, this will be an important result for many different reasons – both from the perspective of the philosophy of science and metaphysics. On the philosophy of science side, it is striking that many proponents of scientific entity realism favour a nominalist (i.e. deflationist) approach to properties. For example, although Devitt is a staunch realist about unobservable property bearers, he leans in some of his work towards what Armstrong calls an 'ostrich nominalist' theory about properties (Devitt 1980). According to ostrich nominalism, predicates carry no ontological commitment whatsoever, and those who ask for a metaphysical analysis of property talk, such as Armstrong (1978), can safely be ignored. Meanwhile, Smart leans towards a set nominalist view of properties, on which scientific predicates merely specify certain interesting sets of physical entities (1987, 184). It would be a striking result, therefore, if the form of argument that Devitt and Smart employ in the case of physical entities could also be applied to the theoretical properties had by those entities. This would show that the combination of scientific entity realism and nominalism about scientific properties is problematic – something that many prominent scientific realists seem not to have noticed. In the other direction, it would also be welcome news in metaphysics that a science-based, abductive argument for

2 It is tempting to call these 'dispositional' properties, but I have decided against using this terminology. The reason is that some people use the terms 'dispositional properties' and 'powers' interchangeably. Hence, by expressing my argument in terms of dispositional properties, this might misleadingly suggest that my abductive argument is an argument for a powers theory of properties. As explained in the next section, the abductive argument presented in this article is compatible with both the categoricalist and powers theories of properties.

realism about properties is available. Most prominent arguments for realism about properties have an *a priori* or unscientific flavour: they tend to be conceptual, semantic, or based on the apparent need to analyse observable everyday phenomena such as resemblance (see Armstrong 1978 and Lewis 1983 for surveys of metaphysical and semantic arguments for property realism). As such, scientific practice and theory have not always played a prominent role in arguments for property realism. Armstrong's 1983 discussion of laws of nature in the context of property realism has a more scientific flavour, but many of the examples he uses concern macroscopic phenomena. Moreover, Armstrong's argument relies heavily on the rejection of empiricist (Humean) theories of laws. Hence, it would be welcome news for realists if there was an argument for property realism that is based more squarely in scientific rather than metaphysical considerations.

The argument that shall be developed in the following sections is anticipated by some brief comments by Brian Ellis (1987). As indicated above, Ellis suggests that the scientific realists' abductive strategy might be applicable to entities other than physical entities like electrons and quarks. He refers to properties as a case in point (Ibid. pp. 65–67) but Ellis's argument is sketchy. For example, Ellis provides little detail about what it is that theoretical properties are supposed to explain (Ibid. 57). And apart from a few passing comments about set nominalism (Ibid. 57), Ellis says little about why rival antirealist property theorists cannot themselves provide an adequate explanation for the patterns of observation we find in science. My aim in this article is to fill in the details and provide a point of departure for further discussions of abductive metaphysics and realism about various ontological categories. In particular, I shall argue that causally efficacious properties are needed to explain three kinds of observational pattern that are found in science.

2 The Scope of This Article

Before proceeding to the main argument, some clarifications about the scope of the article are in order. First, although I shall argue that a realist abductive inference is justified in the case of scientific properties, it is not the aim of this article to provide a defence of abductive inference in general. My main conclusion is just that *if* one accepts abductive scientific arguments for theoretical property bearers such as particles, then one should also accept a parallel abductive argument for realism about certain theoretical properties. For the purposes of this article, then, I shall simply assume that abduction is a legitimate form of reasoning in some cases. I note that the scientific realists' use of abduction has been criticised by (among others) Hacking (1983, pp. 53–55) and van Fraassen (1989, pp. 131–170), and I direct the reader to Devitt 1997, Ch. 7 and 8, for replies. For an excellent book-length treatment of inference to the best explanation, see Lipton (2004), and for recent discussions and defences of inference to the best explanation, see Mackonis (2013) and Dawes (2013). I shall also not say much about the distinction between observables and unobservables. There are reasons to think that this distinction is not sharp (see e.g. Hacking 1983, Ch. 10 and 11, for a discussion of borderline cases). For the purposes of this article I shall assume that the properties we find in physics, such as charge and spin, qualify as unobservable phenomena but this assumption is not essential for the argument proposed.

Second, the article will not say much about the specific form of property realism that we should accept. As far as I can tell, the abductive argument to be discussed allows one to conclude only that *some* form of realism about properties should be accepted. Those familiar with the metaphysical literature on properties will know that property realism comes in many different flavours. For example, some realists think of properties as universals, which are repeatable and identical across their instances. In contrast, trope theorists insist that properties are non-repeatable abstract particulars, such that instances of a property are each distinct. Thus, according to most trope theorists, to say that two things share a common property is to say that those things possess distinct tropes that closely resemble (see Armstrong 1989 for a good introduction to the universals versus tropes debate). Again, the abductive argument for property realism is neutral as regards these realist in-house disputes. The universals or tropes that a substance instantiates are equally suitable for explaining the behaviours of their bearers. Indeed, as far as this article is concerned, we can also be open to the idea that the best metaphysical account of properties (realistically construed) is yet to be developed. For example, although Ellis (1987, 66) is attracted to the abductive argument for property realism, he is doubtful that existing realist views can provide a good account of the quantitative nature of scientific properties. Recently, Cowling (2014) has argued that a new 'locationist' theory of properties fares better in this regard, on which properties are points or regions in a real *n*-dimensional quality space.

There is also a lively contemporary debate about whether properties are fundamentally categorical or whether they are nothing more than powers. According to some property theorists, the causal dispositions of things are grounded in their categorical properties, where a categorical property is one that has a self-contained primitive essence (see e.g. Armstrong, 1997, Ch. 5). According to other property realists, properties have a powerful rather than categorical essence and therefore dispositions need not be grounded in a categorical base (see e.g. Bird 2007 and Mumford 2004). There are also property realists who think that the categoricalists and powers theorists are both partially correct: properties are 'powerful qualities' and have both a categorical and powerful aspect to them (see e.g. Heil 2003, Ch. 11 and Engelhard 2010). Again, for the purposes of this article, we may remain neutral as to whether properties are fundamentally categorical, powerful or both. All that matters for our purposes is that the properties posited are *causally efficacious*, and indeed categoricalists, powers theorists and powerful qualities theorists all accept that the properties they posit are causally efficacious. On most categoricalist theories, for example, it is categorical properties that are ultimately responsible for the causal behaviours of things—in conjunction with the laws of nature—and dispositions are merely inert second-order properties of things: properties of having first-order (categorical) properties that play certain causal roles (e.g. Prior, Pargetter and Jackson 1982). This is a thesis that McKitrick (2018, Ch. 9) calls the 'Inert Dispositions Thesis' and it is one that she argues against. If dispositions can be their own causal base, as McKitrick urges, this opens up the alternative possibility of properties being fundamentally powerful rather than categorical. The conclusions of this article are compatible with either outcome. In sum, further metaphysical work is needed to establish whether the real causally efficacious properties are universals or tropes, or whether they are fundamentally categorical or powerful.[3]

Next, it must be acknowledged that this is by no means the first article to argue for properties based on causal considerations. It is common, particularly is the literature on tropes, to argue that ordinary causal claims are best interpreted in terms of a metaphysics of tropes (e.g. Campbell 1990 Ch. 5 and 1997, Ehring 2011 Ch. 3, Williams 1953). However, these arguments differ from the abductive strategy explored in this article. Those arguments for tropes typically proceed by examining the grammar of specific causal claims and showing that if we take such claims at face value, we should interpret the causal connections involved as being between *property instances* of objects rather than objects taken in their entirety. Moreover, the examples typically involve macroscopic causation rather than theoretical cases in science. For example, Campbell asks us to consider a case in which the weakness of the cable causes the bridge to collapse (1997, 129), or a case where the heat of a stove causes a burn to the finger (1990, pp. 22–23). Campbell urges that 'the conditions referred to in these examples … are properties, but the specific particular cases of properties involved in particular causal interactions' (1997, 129). Although that argument differs from the one presented in this article, there is no reason why the

3 For what it's worth, my view is that properties are Platonic universals (2013) and that they have a qualitative aspect to them as well as a powerful aspect (2012).

two arguments could not work together to strengthen the overall case for property realism. However, I would be reluctant to say that either argument favours trope theory over realism about universals. For example, as long as a realist about universals has a suitable notion of property instances in their theory, they can deal with Campbell's causal examples just as well as trope theory – or so it seems to me.

In recent literature, work on properties and causation has taken a more scientific approach. For example, there is a debate, initiated by powers theorists, on whether the properties posited in theoretical science might favour realism about fundamental powers. The thought is that because such properties (like charge and spin) are properties of simple particles, there is no sense in which such properties could have a categorical base. This is what Williams (2011) calls the 'argument from science' (see also Ellis 2001 Ch. 3, Molnar 2003, Mumford 2006, Bird 2007 and Hüttemann 2009). Williams himself argues that this argument is not conclusive and that, as far as science is concerned, fundamental particles might have a categorical aspect to them. I am inclined to agree with Williams on this point, but as far as this article is concerned we may remain neutral on this issue. As explained above, the aim of the abductive argument is to establish realism about causally efficacious theoretical properties. To repeat, whether or not these properties are categorical or powerful is a further question that we shall not address.

A final clarification to make is that the abductive argument to be discussed only allows us to establish the existence of a limited set of properties, namely various theoretical properties in science that allow us to give a systematic explanation for various experimental patterns that we observe. Thus, the abductive argument can only be used to establish a sparse, *a posteriori* version of property realism. The argument remains silent on whether there are also 'abundant' non-scientific properties (see Lewis 1983 on the sparse/abundant distinction). That said, Devitt (1997, Ch. 5) has argued that abduction can be used to establish realism about ordinary observable objects ('Common-Sense Realism') as well as the unobservable objects of science. So, it might be that a parallel abductive move can be made to establish realism about observable macro-properties in addition to theoretical properties in science. Again, I shall leave this particular issue for future work.

3 The Abductive Argument in Outline

In Ellis's 1987 he provides us with a sketch of an abductive argument for realism about properties. After introducing the scientific realist abductive argument for the reality of particles, he writes (1987, 57):

> It is also, prima facie, an argument for the existence of certain properties, for example the properties that these particles are supposed to have. For, we may ask, 'Why do the fundamental particles behave *as if* they had these properties?' The only satisfactory answer seems to be: 'because they actually do have these properties'.

Here Ellis identifies the two premises of an abductive argument for scientific properties. The first premise is that particles behave *as if* they have properties. The second premise is that the best explanation for this behaviour is that particles really do have these properties. These two premises then give us the ingredients for the abductive inference that establishes the reality of the particles' properties. As it stands, however, the argument is not very detailed. What does it mean to say that particles behave *as if* they have properties? Since we cannot directly observe fundamental particles, presumably such 'behaviour' will itself have to be inferred from the observable data that we yield from our scientific instruments. The important question, then, is this: what kinds of experimental observations make it appear as though particles have various properties as opposed to no properties at all? Until we have answered this question, it is not clear what the first premise commits us to, nor what its justification might be. The proposal I develop in the sections below is that this first premise is supported by three kinds of observational pattern in science: behavioural similarity at a time, behavioural similarity over time, and the phenomenon of disposition clustering.

It is also not clear why the second premise supports the inference to realism about properties. For example, some nominalists might happily accept that particles have properties and that this explains why particles behave as if they have properties. Nominalists are typically deflationists about properties rather than eliminativists, and so they need not deny that things have properties (in some sense). Why then does our explanation of the particles' behaviour require a commitment to realism about properties as opposed to some non-eliminativist form of nominalism? Although Ellis briefly discusses set nominalism (1987, 57), he says nothing about other popular forms of nominalism, nor does he consider possible explanations for observable behaviour that do not appeal to properties at all. We shall explore these issues further in sections 7 and 8.

4 Behavioural Patterns and the Experimental Method

Let us proceed then by developing and defending the premises above in more detail. What does it mean to say that something is behaving as if it has properties? And more precisely, what kinds of experimental observations would lead us to think that theoretical entities are behaving as if they have properties? In order to approach these questions, it is helpful to begin by considering the nature of scientific experimentation itself. First and foremost, what systematic scientific experimentation reveals are *patterns* of behaviour in nature rather than singular, isolated causal events. In particular, there are three kinds of pattern that shall be discussed in the sections below, which are what I call patterns of differential similarity, uniformity, and disposition clustering. What underlies all these patterns is the fact that physical entities have various behavioural dispositions to interact with other things in various ways, and when experimenting our aim is to manifest more and more of these dispositions so that we can formulate laws and draw inferences about what lies behind this behaviour. But to be clear, to say that experiments reveal dispositions is not already to presuppose that there are real universals or tropes. As we shall see later in sections 7 and 8, there are theories which take dispositions metaphysically seriously but which offer a nominalist analysis of properties. As we shall understand the term, to say that something has a disposition is just to say that a certain subjunctive/counterfactual truth holds of it. Whether or not real properties (universals or tropes) are the source of those truths is a further question. The conclusion will be, of course, that real properties are indeed needed.

When one reflects on the preconditions of fundamental scientific enquiry, it is no surprise that the experimental method is restricted to telling us about the behavioural patterns in the world. When our enquiries about the world go beyond the realm of medium-sized dry goods, we can only rely on the help of experimental instruments. Such instruments allow us to causally interact at scales far beyond the reach of our perceptual capacities. This is not to say that our instruments give us direct epistemic access to the world at the microscopic or cosmic scales, because all our instruments can ultimately show us is how the world is *disposed to interact with our instruments*. If we were to alter the design of our instruments, then the causal consequences of our experiments might be different. So, the experimental data we gather says as much about our instruments as it does the world. In short, our observable experimental data only goes as far as showing us how the world and our instruments *interact*. If we want to move from knowledge of those interactions to knowledge about what the world is like in itself, this takes theoretical work, as the abductive strategy illustrates. Williams (2011, 77) sums up the situation nicely as follows:

> We are restricted, as it were, to poking and prodding at them with bombardments, and 'seeing' (through instruments) how they react. This informs us about the reactions, responses, and outputs that the fundamental

entities produce in response to testing; it tells us what behaviour the entities exhibit.

In summary, the experimental method delivers, and can only deliver, patterns of behaviour. Hence, from a scientific perspective, to say that some theoretical entity behaves *as if* it has properties is to say that certain patterns of behaviour are observable. What, then, are these patterns? What observable patterns give the appearance of there being properties as opposed to no properties at all? It is to this question that we now turn in the following three sections. In short, the answer is that properties can explain the following kinds of behavioural pattern: 1) behavioural similarity at a time (differential similarity); 2) behavioural similarity over time (the uniformity of nature); and 3) what I call the phenomenon of disposition clustering. It is only when these behavioural patterns arise that the abductive inference to real theoretical properties can and should be made. Let us now discuss each of these patterns in turn and explore how the abductive inference can be drawn in each case.

5 Differential Similarity in Behaviour

Suppose that, at a given time, two things that are otherwise distinct appear to behave in similar ways in similar circumstances. For example, imagine that we experiment with two particles in a laboratory, an electron and a muon. Suppose also we do not know much about these particles, but find out through our instruments that they manifest different gravitational behaviour. On this basis, we naturally conclude that the two particles are not of the same kind. However, suppose further that we discover the two particles manifest the same electrostatic attraction or repulsion when in the presence of certain other matter. What inferences can be drawn from all of this? Well, this is a case in which the two particles are behaving *as if* they really are similar in some ways but not others. To be precise, the evidence suggests that they are similar in respect of charge but not in respect of mass. If that is right, then for the same reason that the scientific entity realists accept the existence of particles, it seems we should accept the existence of ways or respects in which things can be behaviourally similar (or different). As per premise two of the abductive argument, the reason is that these ways or respects of similarity *provide the best explanation for why certain entities exhibit similar behaviour in some cases but not others*.

Of course, the realists about properties can concede that our scientific explanations of observable behaviour might not explicitly appeal to properties.

Being told that a certain particle manifests a certain electrostatic force *because it is an electron* might explain that behaviour in some sense. But it seems plausible that such an explanation is informative only because e*lectrons have the causally efficacious property of unit negative charge*. If it is a precise, fine-grained explanation of the electrostatic attraction or repulsion that we are looking for, it is plausibly the charge property which explains the electrostatic behaviour. The electron *qua an entity with mass* surely has no explanatory role to play here, because we know that particles with different masses can exhibit the very same electrostatic behaviour. Mass, then, plays a different causal-explanatory role, which is to explain gravitational or inertial behaviour. Given these explanatory roles, the argument from scientific realism suggests that it only makes sense to be a realist about entities if one is also a realist about properties. The inference is relatively simple: The scientific realists' entities behave *as if* they are similar in some respects *but not others*. And the best explanation for this is that there really are ways in which those things are similar and ways in which they are different.

Importantly, the argument just outlined also satisfies a more general abductive principle that has been discussed by Schaffer in an article about Armstrong's governing theory of laws.[4] There, Schaffer proposes that our fundamental posits are only legitimate if they are not idle: they must do theoretical work for us (2016, 579 and 583). The argument of this section is precisely that property realism is justified in a scientific context because properties allow their possessors to make a differential causal contribution to the world. Indeed, if entity realists posit entities which are not endowed with real, causally efficacious properties, it is difficult to see how they could satisfy Schaffer's requirement. In contrast, entities endowed with causally efficacious properties are certainly not idle, because if such properties exist, then the kinds of behavioural pattern we find in the world are precisely what we should expect. As we shall now see, this point also holds in relation to patterns of uniformity and patterns of disposition clustering.

6 Consistency of Behaviour Over Time (the Uniformity of Nature)

The previous example of a behavioural pattern concerned distinct entities at a time. But the experimental method also reveals things about entities *over* time. In such a case, what we tend to see is that, if left untampered with, a physical entity will continue to exhibit the same behaviour (or in probabilistic cases,

4 I am grateful to an anonymous referee for pointing out this connection.

similar statistical patterns of behaviour) in response to a given experimental set-up. For instance, if on one occasion a particle manifests a certain electrostatic attraction or repulsion when in the presence of certain other matter, we will typically find that if that same situation is replicated later on, the particle will exhibit the same electrostatic behaviour (as long as the particle has not been interfered with in the intervening period). Let us call this pattern of repeatability over time the *uniformity of nature*.

What can explain the uniformity of nature from a scientific realist perspective? As with the case of differential similarity at a time, it seems wholly natural to appeal to underlying causally efficacious properties out there in the world. The explanation for why the aforementioned particle behaves as if it has the same dispositions at different times is that it has a property which it keeps over time—regardless of whether we happen to be causally prodding that property. According to this explanation, the uniformity of nature rests on the fact that we live in a world of things with stable, causally efficacious properties that are not always made manifest to us. To return to the case above, the particle exhibits the same electrostatic dispositions on each occasion because it had a certain property on each occasion—namely a given charge. And the reason it had the charge on both occasions is that charge is a real, persisting feature that it keeps over time but which reveals itself only some of the time.

At this point, a critic might worry that such an explanation is trivial and uninformative. Saying that the particle was charged on both occasions might not seem to give a very illuminating explanation for the fact that the particle displayed the same electrostatic behaviour on those different occasions. This sort of worry could be raised for all three of the explanatory cases being discussed. Here, critics might point out that we have little conceptual grip on the nature of charge other than by reference to the fact that it causes electrostatic attraction. Indeed, the dictionary definition of charge seems to support this thought. Consider, for instance, the following characterisation of charge in the Oxford Dictionary of Physics (Isaacs, 2000):

> Charge: A property of some elementary particles that gives rise to an interaction between them and consequently to the host of material phenomena described as electrical. … Two particles that have similar charges (both negative or both positive) interact by repelling each other.[5]

Clearly, in this entry charge is characterised as precisely that which helps to explain, or 'give rise to' various observable behaviours associated with certain

5 I discovered this quotation in Mumford 2006, 476.

elementary particles. One might therefore worry that saying that the charge property explains the electrostatic behaviour amounts to saying that the cause of F is the cause of F. But it is not illuminating to be told that the cause of F is what caused F, given that this claim is an analytic truth.

In response, I think we may agree that in science it is hard to see how we can define certain theoretical properties other than by reference to the experimental behaviour they give rise to. As we saw in section 4, we cannot directly observe the world at small or large scales, and so when doing science at those scales we can only posit entities by reference to the effects they have on our instruments. But does this mean that it is trivial to say that, say, an intrinsic charge property of a particle explains its electrostatic behaviour? It does not. Even if, from a scientific perspective, the charge explanation is akin to saying that the cause of F caused F, this does not rule out a genuine explanatory connection. As Mumford remarks in a different context, it would be absurd to say that the cause of F could not cause F because the former proposition *means* the cause of F (2004, 169). That would be to conflate semantics and metaphysics, and to mistakenly draw a metaphysical conclusion based on the way the cause is being picked out in the relevant proposition.

Returning to the charge explanation, we can also see that it is non-trivial, metaphysically speaking, when we reflect on the fact that there are other conceivable metaphysical explanations for the repeatability of a particle's behaviour, and we can even conceive of there being no explanation at all. This shows that the property realist explanation is not trivial. For instance, it seems logically possible that all fundamental entities such as particles are featureless blobs and that a powerful god somehow decrees that they will always behave in certain ways. In that case, the explanation for the repeatability of behaviour would have nothing to do with inherent properties of particles. Similarly, perhaps one could appeal to external primitive laws of nature that somehow dictate how featureless blobs are to affect our experimental instruments. Alternatively, perhaps the behavioural regularity (or statistical regularity) that we find in the world is just a brute fact, and not to be explained by anything. Indeed, this is the position that Humean naïve regularity theorists about laws seem to hold, at least where fundamental regularities are concerned.

Before discussing a further explanatory need that arises in science, one final important point should be highlighted about the uniformity of nature. It is arguable that the uniformity of nature is an integral part of not only a scientific realist argument for properties *but also for the existence of the things that have properties*, such as atoms, electrons and so on. Without the uniformity of nature, it is difficult to see how we could ever get a firm grip on the idea that our instruments detect mind-independent objects. Imagine, for instance, that although every experiment generated causal data, the uniformity of nature did not hold, so that the world's behaviour changed radically from one moment to the next. In such a case, suppose that the same kinds of instrumental stimuli never gave rise to the same instrumental responses. If that were the case, we would surely begin to lose a grip on the idea that there were stable unobservable entities responsible for the instrumental effects. Unless such effects occurred repeatedly and uniformly, the user of the instrument would surely have little reason to infer anything other than that the instrument behaves randomly of its own accord. In short, it seems that the uniformity of nature is a necessary part of any scientific realist framework, such as that of Cartwright, Devitt and Smart discussed earlier. And importantly, if a plausible explanation for this uniformity requires us to posit stable, causally efficacious properties, which exist even when they are not manifested to us, then it seems a belief in such properties is necessary for the formation of *any* beliefs that reach beyond what is immediately observable. If this is right, then the scientific realist case for property realism is even stronger than Ellis himself may have realized. Rescher (2000, 32) illustrates the point with the case of an apple (here he refers to unmanifested properties as 'latent sectors').

> The existence of this latent sector is a crucial feature of our conception of a real thing. Neither in fact nor in thought can we ever put it away. To say of the apple that its only features are those it actually manifests is to run afoul of our conception of an apple. To deny—or even merely to refuse to be committed to the claim—that it *would* manifest particular features *if* certain conditions came about (for example, that it would have such-and-such a taste if eaten) is to be driven to withdrawing the claim that it is an apple.

7 Patterns of Disposition Clustering

We now come to the final sort of behavioural pattern that cries out for explanation. It is striking that in all branches of science, we find specific patterns in the way that determinate dispositions are distributed. Dispositions, to recall, relate to the subjunctive facts concerning an entity's behaviour. In particular, our world contains many regularities in terms of how behavioural dispositions 'cluster' around various physical entities. For instance, when a medium-sized object is spherical, it has the disposition to roll down a hill (in the presence of gravity) as well has the disposition to affect our visual capacities in a certain way (in the presence of certain lighting conditions).

Now, we can often explain dispositions at non-fundamental levels of nature by appealing to reductive explanations at lower levels. For example, the disposition of a macroscopic object to reflect light in a certain way can be explained in terms of microscopic properties like molecular structures and their vibratory behaviour. Hence, we might expect that disposition clustering at the macro-level can always be explained by mechanisms at lower levels, so that the clustering patterns are no longer surprising. Matters are not quite so simple in the more fundamental sciences, however, because reductive explanations may not be available. And importantly, disposition clustering occurs in all areas of nature. Entities that are disposed to resist certain forces to certain degrees also have certain gravitational dispositions. Particles that have a disposition to undergo a certain electrostatic force when in certain electric fields also have the disposition to undergo certain Lorentz forces when in certain magnetic fields. These are all different kinds of dispositions, since they have distinct triggering conditions and result in different kinds of observable behaviour. It is even the case that many dispositions of the same kind are regularly had by physical entities. For instance, in the case of charge, we find that if a particle is disposed to experience a force of 3 dynes when in a field of 1 dyne per statcoulomb, it will also be disposed to experience a force of 6 dynes in a field of 2 dynes per statcoulomb.[6] Indeed, a charged particle will have an infinite number of such dispositions, given that the laws concerning charge, such as Coulomb's law, are functional. For our purposes, it is important to emphasize that each of these specific dispositions is distinct in the sense that they involve different triggering conditions and different behavioural manifestations.

Such cases of disposition clustering are pervasive across all domains of science. Kistler (2012, 123) acknowledges this point and offers a range of examples including other cases from physics. For example, he points out that there is a range of dispositions associated with electrical conductivity, which manifest in current density as well as thermal conductivity (Ibid. pp. 122–123). Kistler also discusses iconic memory in cognitive psychology (Ibid. p. 123), instances of which always involve a range of distinct reporting dispositions. In chemistry, we find that acids regularly have the disposition to dissolve certain things, the power to burn, to taste sour, to react with metals, and so on.

How, then, are all of these correlations to be explained? As we saw earlier, there may be reductive mechanistic explanations in some cases, but this will

6 This example is borrowed from previous work (Tugby 2016, section 4.6), where I appeal to the phenomenon of disposition clustering in an argument against the causal nominalist theory of properties (more on this later). Kistler (2012, 2020) also discusses the case of elementary charge in order to argue for a distinction between 'powerful properties' and dispositions.

not always be the case, especially at the fundamental level of physics where there are plenty of examples of disposition clustering. In these cases it seems the only metaphysical explanation available is that the array of behavioural dispositions is explained by the presence of a small number of underlying properties, which serve to ground (at least in part) and unify the dispositions in question. For example: A natural explanation for a scientific realist is that a body has certain inertial and gravitational dispositions because it has a certain mass. A particle has electrostatic and Lorentz dispositions because it has a certain charge. And more specifically, the reason why a particle with the disposition to experience a force of 3 dynes in a field of 1 dyne per statcoulomb also has the disposition to feel a force of 6 dynes when in a field of 2 dynes per statcoulomb is that the particle in question has the determinate charge property of 3 statcoulombs. In short, an important role that causally efficacious universals or tropes are well placed to play is that of helping to explain the regularities we find in disposition clustering.

In line with the comments in section 2, properties are well placed to play this role regardless of whether they are fundamentally categorical or dispositional. If the properties are categorical, the idea would be that the various dispositions of, say, a charged particle are unified by the fact that the particle instantiates a determinate categorical charge quantity that falls under the laws associated with charge. If, in contrast, properties are fundamentally powerful then the account of disposition clustering would be along the lines of that proposed by Ellis (2001) and Kistler (2012, 2020). According to Ellis, the various determinate dispositions associated with a property like charge, of which there are infinitely many, are called 'behavioral dispositions' (2001, 120), and these dispositions are all grounded in a single determinate dispositional property universal, such as the property of 3 statcoulombs. Kistler (2012, 2020) has a structurally similar view on which a single 'powerful property' underlies and unifies the associated 'multi-track' dispositions.

Finally, it is important to clarify that these arguments are not meant to imply that scientists themselves should include the property realists' explanations as part of their physical theories, for such explanations fall squarely within the remit of metaphysics. Moreover, we should not assume that all properties discussed in science can be used to unify multiple determinate dispositions in the way suggested. Perhaps, for example, there are some cases in which a property term is used as 'shorthand' for conjunctions of more basic properties, each of which confers its own unique dispositions. This could be the case with 'mass', since there is an ongoing debate about whether there are two kinds of mass, one giving rise to inertial dispositions and the other to gravitational dispositions. Nonetheless, it seems plausible that in at least some cases of disposition clustering, there is a unifying property which grounds the cluster. As Kistler (2020, Sect 11.2) illustrates, this seems especially plausible in the case of elementary charge.

8 Objections Considered: Are Real Properties Worth the Price?

With the core abductive argument in place, let us conclude by considering some possible responses from those who resist property realism. As acknowledged earlier, the abductive argument for properties would not be, and indeed has not been, accepted by all scientific realists. Although Smart is a well-known advocate of scientific entity realism, he admits that although he is attracted to property realism, he is doubtful 'how to work it out' (1987, p. 183). In particular, he notes that many properties in fundamental science are quantitative, whereas realist views about properties tend to apply more naturally to qualitative properties. As a result, Smart is inclined to reduce properties to sets of individuals rather than to accept that properties exist in their own right (Ibid. p. 184).

In some ways I sympathise with this worry. Properties are metaphysically puzzling for a number of well-known reasons, relating, for example, to the issue of instantiation and Bradley's regress. But does the difficultly of providing a problem-free realist theory of properties provide a good reason for *ruling out* the existence of universals or tropes? I do not think so. I believe that what this article helps to show is that if one takes abductive scientific realism seriously then one should make an effort to *develop* a realist theory of properties, given the explanatory rewards that it promises.

Returning to Smart's preferred approach, the main problem is that it is unclear how a deflationary set nominalist view of properties can do any explanatory work where behavioural patterns are concerned. As mentioned above, Smart leans towards a view on which properties merely pick out sets of things. On this view, to say that things share a certain scientific property is to say that those things naturally belong to the same set. Thus, propertyhood is reduced to the notion of set membership and naturalness. There are many well-known objections to this view (see e.g. Armstrong 1978, Ch. 4), such as the worry that the view puts the cart before the horse. Surely, things naturally belong to certain sets *because of the properties they have* rather than vice versa. I shall not discuss these objections here, however. For our purposes it suffices to point out that it is mysterious how set membership can help to explain the behavioural patterns that worldly objects exhibit. How can a set, which is an abstract grouping of objects, determine the behaviour of each of its members? It is difficult to see how such an explanation could work.

To be fair to Smart, he was no doubt aware of the explanatory limitations of set nominalism and does not claim to be offering any deep explanations for worldly patterns of behaviour, which may explain why he later defends a version of the regularity theory of laws (1993). This seems a surprising route for a scientific realist to take, however. Typically, the regularity theory goes hand in hand with empiricism. The regularity theory or some variant of it is pretty much unavoidable for full-blooded empiricists, given that they lack the resources for going beyond what is observable, i.e. beyond the experimental regularities. However, given that Smart is a scientific realist, such a route is surely avoidable. And by not avoiding that route, Smart is left with a disjointed picture of the world. On the one hand, Smart is prepared to accept that entities like sub-atomic particles are fundamental existents because the world appears *as if* such particles exist. Yet, at the same time he denies that properties are fundamental existents, even though, as I have argued, the world behaves *as if* entities like particles possess some persisting, causally efficacious properties but not others. Given that scientific realists value explanatorily rich metaphysical theories (unlike the empiricists), it is surprising that Smart does not embrace realism about properties.[7]

Could a more sophisticated version of set nominalism provide a more illuminating explanation for the patterns of behaviour discussed earlier? Interestingly, in recent literature some powers theorists have seriously considered a nominalist variant of their view, namely, Whittle (2009) and McKitrick (2018, Ch. 2). Neither Whittle nor McKitrick endorse this form of nominalism wholeheartedly; McKitrick's dispositional pluralism allows that universals and tropes may still be needed in some contexts (2018, 99), while Whittle has endorsed a trope theory in other work (2008). Nonetheless, it is worth considering whether a nominalist version of the powers theory can deliver the sorts explanation that I have claimed are delivered by causally efficacious universals or tropes. Unfortunately, it is doubtful that it can.

The basic idea behind this recent form of nominalism is that 'something having a power is a matter of an irreducible counterfactual holding of it' (McKitrick 2018, 98). On this view, there are irreducible counterfactuals/subjunctive facts about what particulars can do, facts that are not grounded in universals or tropes that they instantiate. If one likes the idea that all natural properties are powers, one can then give a general account of natural properties in set-theoretical terms. We can say that some property is the set of particulars all of which share certain counterfactuals/subjunctives in common (Whittle 2009, 248). Importantly for our purposes, one might then think that

7 As mentioned earlier, the same conclusion can be drawn with respect to Devitt's work.

these irreducible counterfactuals could serve to explain the behaviours of things just as well as causally efficacious universals or tropes.

Unfortunately, the explanations delivered by power nominalism can only take us so far. While primitive counterfactuals/subjunctives might provide explanations for behaviour in some of the examples considered earlier, they will not do so across the board. Consider, again, the case of charge discussed in the previous section. Charged entities have an infinite number of determinate dispositions, depending on which determinate value of charge they have. However, on the nominalist view we are considering each of these dispositions will correspond to a *distinct* primitive subjunctive fact, facts like 'if the particle were in a field of 1 dyne per statcoulomb, then it would experience a force of 3 dynes' (Tugby 2016, 87). The problem is that the conjunction of all those distinct subjunctive facts remains unexplained: it turns out to be a brute fact that charged things have the array of dispositions that they do. In order to provide an explanation, one option is to appeal to governing laws of nature as a way of unifying the various subjunctives, but this would surely undermine the main motivations behind the powers theory, which is to provide a metaphysics that does without governing laws.[8] In the light of this worry, the obvious alternative is to reject nominalism and accept that the relevant array of dispositions is unified and grounded by a determinate charge universal or trope.

Finally, can any other versions of nominalism do better when it comes to explaining the behavioural patterns that physical entities exhibit? I doubt it. The ostrich nominalism that Devitt defends in 1980 is simply not in the business of explaining why certain predicates apply to some objects but not others. To say that a particle exhibits certain patterns of behaviour is precisely to predicate certain features of it. But predication is primitive and goes unexplained on the ostrich nominalist approach. Resemblance nominalism is more ambitious in its explanatory aims, since it tries to explain properties in terms of primitive relations of resemblance. And thanks to the work of Rodriguez-Pereyra (2002), resemblance nominalism has made progress in responding to its main objections. Nonetheless, it is difficult to see how a resemblance nominalist can provide an explanation for the behavioural patterns discussed earlier that is better than the one provided by property realism. According to resemblance nominalism, to say that a set of things share the same property is to say that those things primitively resemble. But why, we may ask, should

8 In previous work (Tugby 2016, 94) I discuss other reasons why a power nominalist should not accept a governing laws view. For example, the most obvious way of understanding a governing law is to view it is a relation between universals, but of course acceptance of universals would undermine power nominalism.

the behavioural patterns exhibited by a particular particle have anything to do with its relations of resemblance to other things? The problem here is essentially the same as that facing set nominalism. Like set membership, resemblance is a relational property and it is difficult to see how a thing's resemblance relations to other things should determine its intrinsic behaviour. Surely the dispositions of a particle would remain the same even if it didn't happen to resemble anything else. The same goes for those versions of nominalism that make propertyhood mind-dependent, such as predicate or concept nominalism. Imagine that minded creatures had not existed and therefore that the relevant predicates or concepts corresponding to the property of charge did not exist. Surely particles would still have engaged in electrostatic behaviour in the way that they do. This strongly suggests that those nominalist approaches cannot provide an explanation for the behavioural patterns that scientists observe.

9 Conclusions

The aim of this article has been to show that if one is attracted to the abductive approach to scientific entity realism, then one also has good prima facie reasons for accepting property realism. Among other things, such properties help to remove the apparent coincidence of distinct dispositions regularly clustering together. Persisting mind-independent properties are also naturally invoked when explaining the uniformity of nature and the differential similarities in behaviour of physical entities. In sum, I propose that by focusing on the aforementioned behavioural patterns—concerning differential similarity of behaviour, the uniformity of nature and disposition clustering—we can provide a detailed account of how and when a real theoretical property should reasonably be posited. This conclusion is striking for a number of reasons. In the philosophy of science literature, many scientific entity realists are not property realists, which suggests the parallels drawn in this article have gone unnoticed by many. And in the metaphysics literature, arguments for property realism tend to be based more on conceptual or semantic considerations. If the arguments of this article are sound, there is a more scientifically orientated argument for metaphysical realism about properties, one which deserves further attention in future work on properties. Indeed, a broader lesson to draw from this article is that metaphysics can benefit from engagement with scientific practice. This is what scientific realists have been doing for a long time, but many of them have been too narrowly focused on what I have called property bearers. It is time to investigate the application of science-based abductive arguments to entities in other ontological categories.

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