STRUCTURAL PROPERTIES REVISITED

Abstract

Those who hold that all fundamental sparse properties have dispositional essences face a problem with structural (e.g. geometrical) properties. In this paper I consider a further route for the dispositional monist that is enabled by the requirement that physical theories should be background-free. If this requirement is respected then we can see how spatial displacement can be a causally active relation and hence may be understood dispositionally.

1 Dispositional monism and structural properties

1.1 Introduction

Monistic dispositional essentialists (or *dispositional monists*) hold that all fundamental sparse (i.e. natural) universals have essences that are dispositional.[1] Thus all properties either have a dispositional essence or are not fundamental or are not natural. This view is motivated, for example, by the claim originating with Sydney Shoemaker (1980), that the identity of a property is given by its causal (or more generally dispositional and nomic) relations with other properties. An obvious extension of dispositional monism asserts that non-fundamental natural properties are also essentially dispositional or supervene on natural properties that are essentially dispositional.

What one may call 'structural' properties seem to be potential counterexamples to dispositional monism. These are such properties as shape, possessing a certain spatial arrangement of parts, and relations such as spatial separation, or being n-wise distinct. These seem to be purely *categorical*, which is to say that they have no essential powers or dispositions. Instead their distinctive natures are wholly contingent, being dependent on the role they play in the contingent laws of nature. Faced with putative counterexamples, the dispositional monist has three strategies: (i) show that the property in question has a dispositional essence after all; (ii) deny that the property is natural; (iii)

[1] I am assuming that natural properties are universals. But to a large degree my discussion is orthogonal to the issue of whether properties are universals or are better understood as classes of resembling tropes or in some other nominalistic fashion. Ann Whittle ("Causal Nominalism", this volume), for example, develops a nominalistic account of the kind of properties I am interested in here. For my part I have a preference for universals because I cannot see how a substantive or realist conception of the laws of nature can do without them. On any such view laws, or what they flow from, are supposed to provide a unified explanation of the behaviours of particulars. Without universals the explanation of the behaviours of things lacks the required unity. According to nominalism the interaction between electron **a** and positron **b** resembles the interaction between electron **c** and positron **d**, but there is no one interaction type that they both instantiate. Consequently it is difficult to see how a law, regarded as a single entity, can account for both.

show that it supervenes on properties that do have dispositional essences. For example, the relation of being pairwise distinct does not seem to be a natural property. But even if it is, then it supervenes on other properties of material objects: if two objects have non-zero spatial displacement then they are pairwise distinct. The question then reduces to whether displacement has a dispositional essence.

How are we to settle the question whether such properties are essentially dispositional or not? Traditionally it was thought that the following would provide a necessary and sufficient condition of a property P's being dispositional:

(CA) for all x, and for some S and M:

x is P *entails* were x to be S, then x would be M.

Now it was also once thought that being dispositional was somehow disreputable, as shown by the above relationship with subjunctive conditionals, and that dispositional properties should somehow be reduced away to categorical ones. Hugh Mellor (1974) sought to show that dispositional properties were being traduced and that even allegedly respectable categorical properties had the same relationship to conditionals as dispositional ones. Mellor's example was:

> x is triangular *entails* were one to count the corners of x, the answer would be three.

One possibility for settling the issue over the nature of structural properties is this. We can abstract away from the motivation of the ensuing debate between Mellor and Elizabeth Prior (1982) to use his argument to show that properties such as triangularity are after all essentially dispositional. I attempted this in (Bird 2003), but with what I now regard as only partial success. In this paper I revisit the question to propose a different and rather better way of making progress with the question.

1.2 Conditionals and dispositional essences

The test for an essentially dispositional sparse property derived from (CA) would be:

> (D) 'P' denotes a an essentially dispositional sparse property iff for all x, and for some S and M, x is P *entails* were x to be S, then x would be M.

There are various problems with (D). First of all, the right hand side fails to provide a necessary condition on a property's being dispositional. Finks (Martin 1994) and antidotes (Bird 1998) show that dispositions may fail to entail a subjunctive or counterfactual conditional. In the first case, the disposition may be removed momentarily after it receives its appropriate stimulus, but before the manifestation can come about. In the second case the normal operation of the disposition may be interfered with, preventing the manifestation from occurring.

Furthermore, the test fails to provide a sufficient condition for being an essentially dispositional sparse property. There are three reasons why it fails to do so.

(1) The right hand side of (D) fails to ensure that 'P' denotes a sparse property. For example, one might think that the analysis of the concept of fragility (ignoring finks and antidotes for the moment) is given by:

x is fragile iff were *x* stressed, then *x* would break.

It looks as if according to our test, fragility will come out as an essentially dispositional sparse property. But we should not expect fragility to be a sparse property, let alone an essentially dispositional one. First, we may think that fragility is multiply realized—there are many underlying sparse properties or complexes of sparse properties that will make something fragile. Fragility might be understood as a second order property, 'having some sparse property or property complex such that when an object with the property is stressed, it breaks'. If that is correct then the test tells us that fragility is dispositional. But we wouldn't want this second order property to be necessarily a sparse universal. Some such second order properties might be sparse properties with dispositional essences, but not all.

(2) For (D) to reflect the essences of sparse, natural universals, we want the entailment to hold *de re* whereas it may be true *de dicto*. Consider Armstrong's view of dispositions, according to which it is a contingent law of nature that gives a categorical property its dispositional character at a given world. Thus different categorical properties might support the same dispositional character at different worlds, in virtue of the different laws at those worlds. So '*x* is P' might be true in the actual world and is true in virtue of *x* having categorical property C_0 governed by the law L_0. Because of the analysis of 'P' it is the case that form some S and M, were *x* to be S then *x* would be M. Consider some other world w_1 with different laws; at w_1 *x* is P in virtue of possessing a different categorical property C_1 governed by the law L_1. Thus in each world where *x* is P it is true that were *x* to be S, then *x* would be M. But that is in virtue of a different categorical property in each case. Clearly it is the analysis of 'P' that is doing the work here. It is nothing to do with the nature of the actual property denoted by 'P', viz.C_0, which is distinct from C_1 the property denoted by 'P' in w_1.

(3) The entailment in the right hand side of (D) might hold in virtue not of the dispositionality of P but instead in virtue of the dispositionality of S. Considering Mellor's example, do we want to regard triangularity as supporting the conditional given above? Or does this instead reflect the dispositional character of being a counter? After all, we could hardly regard this anthropocentric conditional as reflecting the essence of a basic geometrical property. A naturalist should reject this as much as she rejects the anthropocentrism of the verification principle, and for the same reasons.

These problems need not cause one to give up the project of using conditionals to test for dispositional essences. Rather they mean that one must be circumspect in employing the test. Consider the test as a necessary condition of being an essentially dispositional property: the failure of the entailment on the right hand side shows that a property does not have a dispositional essence. On so using (D), one should exclude from proposed couterexamples cases where the failure of entailment is a consequence of finkishness or an antidote.

Consider now the test and a sufficient condition of 'P' denoting an essentially dispositional sparse property. The test itself cannot guarantee sparseness, so we should ensure that there is independent reason to think that the property is sparse, e.g. that it it is a natural property that plays a role in scientific explanation. Secondly, one should require that in using (D) to argue that some property has a dispositional essence it must be that case that the entailment is *de re*. That is, '*x* is P' should be read as '*x* possesses

that actual sparse property in virtue of which *x* is P' rather than the *de dicto* reading '*x* possesses some property in virtue of which *x* is P'. That way the entailment is assessed considering the same sparse property at all worlds rather than different properties.

Thirdly, that instead of Mellor's conditional, one should employ a conditional that one may reasonably think could reflect the essence of a fundamental natural property. The essence of property, kind, or thing records the core of fundamental features of the *nature* of that entity. For this reason the essence of *X* does not include just any necessary characteristic of *X*. Thus, as Fine (1994) points out, it is a necessary truth that Socrates belongs to the set of which Socrates is the sole member. But it is no part of the essence of Socrates that he belongs to singleton Socrates. Likewise, it is no part of the essence of Socrates that 2+2=4, even though that is a necessary truth. I note that Fine regards essences as deriving from the *identity* of an entity whereas I have emphasized the *nature* of an entity as the source of its essence. While there may be subtle differences between these approaches, they are not germane to the current discussion.[2] Both the identity and the nature of an essentially dispositional property are determined by the relationship between the stimulus and manifestation. But neither identity nor nature include the necessary conditional 'were *x* struck, then *x* would have been struck' or 'were *x* struck, then 2+2=4.' So not every conditional entailed by '*x* is P' is part of the essence of P. That goes also for Mellor's conditional. Even though entailed by '*x* is triangular', it seems to be a poor candidate for the essence of a property of a kind that one would expect to have a nature not specified in terms of humans and their counting abilities.

The question then arises, in lieu of Mellor's conditional, which conditional should we regard as characterizing the essence of, for example, triangularity (modulo the caveats articulated above). In what follows I shall discuss in general terms what sorts of conditional would be appropriate in characterizing the essences of geometrical and other, more general, spatial properties. The leading consideration will be that the conditionals should be expressed in terms that have a high degree of generality. This is because the essence (which I have identified with the nature) of a property should be the source of its explanatory power. Spatial properties are themselves highly general in their applicability and explanatory capacity. Although an anthropocentric essence for 'triangular' would not prevent its being applicable, even in worlds without humans, that essence would be powerless to explain anything in such worlds. (Perhaps such geometric properties explain little anyway. We shall in due course shift our attention away from them and onto more general spatial properties, principally spatial displacement, which do have general explanatory power.) For this reason, even Coulomb's law fails to have sufficient generality to be the (sole) expression of the essence of spatial relations (for then such essence would the widespread but still insufficiently general property of possessing charge). If one thinks that space and time are fundamental features of the world (which is not guaranteed) or close to fundamental, then one should expect the essence of spatial and hence geometrical properties to be specifiable with respect to other properties that feature in the fundamental laws.

[2]Fine himself slips into talk of nature in more than one place, implying that identity and nature are either the same or closely related.

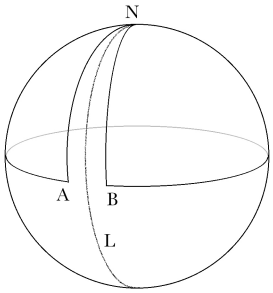

Figure 1:

1.3 Dispositional essences for structural properties—first attempt

Sungho Choi has suggested to me that we could generalize the notion of counting corners. All we would need is a counting machine that can distinguish travelling along a geodesic from not doing so. If it did not do so at any point, then it would add one. Such a machine, travelling along a triangular path, starting at any non-apex point, would count to three on returning to its starting position. Even so, one might hope to find an essence constituted out of properties that one might expect to find in a fundamental theory. In (2003) I suggested the following as a starting point:

> (T) The paths AB, BC, and AC form a triangle *entails* if a signal S travels along AB then immediately along BC, and a signal S* travels along AC, starting at the same time and traveling at the same speed, then S* will reach C before S.

The problem I raised for this suggestion was that this is false for many non-Euclidean triangles. I therefore proposed that the following is true (again barring finks and antidotes):

> (T_E) The paths AB, BC, and AC form an Euclidean triangle *entails* if a signal S travels along AB then immediately along BC, and a signal S* travels along AC, starting at the same time and traveling at the same speed, then S* will reach C before S.

One could then regard 'triangle' as ambiguous, or generic, across a range of triangle-properties, each for different kinds of geometry, and each of which has a different essence of this kind. I suggested triangles in Riemannian geometry or Lobatchevsky-Bolyai geometry might have different (T_i), although in fact (T) will do for many geometrical contexts. In spherical geometry one may consider the figure whose vertices are the north pole, N, and two nearby points, A and B, on the equator and whose sides are the longitudinal arcs NA and NB and the equatorial arc AB that goes the long way round the equator. AB is a little less than $2\pi\times$NA, and so the signal (such as a pulse of light) along AB will take longer to reach B than the signal passing from A to N

and thence to B. Whether this counts as a counterexample to (T) rather depends on the definition of 'straight line' in the context of defining a triangle as a 'figure with three vertices joined by straight lines'. For if a straight line is the *shortest* path between two points, the longer part of the great circle will not be a straight line and our figure is not a triangle, and so no counterexample to (T).[3] On the other hand, if we remove from the sphere the points other than N on a line of longitude L that passes through the narrow gap between A and B, then our figure is a counterexample. On this view, there is no (sparse) property of triangularity in general. Triangularity is a portmanteau term covering different kinds of triangularity. The different kinds have dispositional essences relating to some variant on (T). It is (T) and its family of variants that define triangularity in general.

On drawback for this approach is that it does not demonstrate that the dispositional monist is correct. For where the latter sees a specific and allegedly dispositional property ('being an Euclidean triangle') the categoricalist will see a conjunctive property consisting of a general categorical property plus a specification of the space it is in ('being a triangle in Euclidean space'). The approach considered does not show that the former is correct, at most only that is it is an option. (That may be enough for the dispositional monist given that the properties in question are raised as counterexamples.)

It is in any case far from clear that there is some clearly defined family of variants on (T) that will pick out all and only the triangles in various geometries. Furthermore, it seems a rather convoluted way of characterizing something that can be so easily defined in non-dispsitional terms ('a closed figure bounded by three straight line segments'). The Mellor–Prior debate was about whether being triangular entailed any subjunctive conditional, and happened to focus on one concerning the counting of vertices. But such a conditional would never have sufficed to characterize the essence of triangularity, if triangularity has an essence that is sufficient for something's being a triangle, because many figures have three vertices that are not triangles (not having straight edges). Rather better than either Mellor's suggestion or my (T) is the following:

> The straight line segments AB, BC, and AC form a triangle *entails* were a signal to pass along AB it would not pass through C (and similarly for the other two permutations of A, B, and C).[4]

Even so, I am inclined to think that such conditionals fail to get at the heart of the problem, for two reasons. First, it is difficult to see that anything like a causal or nomic role is being assigned to triangularity. In (2003) I claimed that the connection is causal, while admitting that this could be disputed. I am now less sure. The mere fact of (T) being a counterfactual may confer a spurious appearance of causality. I don't take counterfactuals to be definitive (à la Lewis) of causality. A dispositional essentialist could accept a Lewisian account of causality and add that the counterfactuals arise because of the presence of dispositions. However, it would then seem to make sense to cut out the middle man, counterfactuals, and to regard causal relations as instances of dispositional relations. There is in any case good reason to do so, since *both*

[3] But one could define a straight line as the set of points $L = \{a + tb; t \in S\}$ where a and b are vectors and S is a closed segment of $\mathbb{R}$. In which case both great circle paths are straight lines between A and B

[4] This derives from a suggestion by Philip Welch.

the counterfactual analysis of causation and the counterfactual analysis of dispositions have counterexamples. Perhaps both sets of counterexamples could be eliminated by bypassing counterfactuals altogether?

Matters are, however, not quite so simple. The counterfactual analysis of the basic causal connection is: C causes E iff $\neg C \Box\!\!\rightarrow \neg E$. However, the most obvious dispositional analysis of causation says that C causes E iff E is the manifestation of some disposition whose stimulus is C. If we apply the simple conditional analysis of dispositions to this, we have C causes E iff $C \Box\!\!\rightarrow E \wedge C \wedge E$.[5] So we have this contrast, that the Lewis counterfactual analysis of causation focuses on (counterfactually) *necessary* conditions whereas the dispositional analysis identifies causation with *sufficient* conditions. This suggests that according to a dispositional account of causation, Lewis's approach, along with Hume's claim from which it originates, was misguided from the very start.[6]

We should remember, furthermore, that 'triangular' is unlikely itself to name a fundamental structural property, and the dispositional essentialist is therefore not required to find a dispositional essence for it. The dispositional monist ought instead focus attention on the fundamental structural (primarily spatial and temporal) properties and argue that these have dispositional essences.

2 Dispositional essences for structural properties—second attempt: background-free physical theories

I will now sketch an alternative view of how dispositional essentialism may be reconciled with structural properties at the fundamental level. I shall concentrate on spatial separation (displacement), but the argument carries over to temporal relations also. Our knowledge of the nature of space and time is in a state of flux and we do not know what the role of fundamental spatial and temporal properties will be in the final theory of everything—if indeed we ever get to such a theory. Note that it is not *a priori* that such a theory would refer to spatial and temporal properties at all, nor, if it does, that the fundamental ones neatly mirror the role of such properties in folk physics or even classical physics.

Nonetheless, we can make some prognostications that suggest that a final theory would treat all fundamental properties dispositionally. I will first mention a brief response by Stephen Mumford (2004: 188) to the current problem. The gravitational force on an object is sensitive to both the masses of it and of other massy objects and its displacement from those other objects; looking at Newton's law: $F = Gm_1m_2/r^2$, the force F is a function of the masses m_1 and m_2 and also of their displacement r. Mathematically speaking mass and displacement are on a par—there is no way for Newton's

[5] Note that we need an analysis of counterfactuals for which $C \wedge E$ does not suffice for $C \Box\!\!\rightarrow E$—which it does according to Lewis and Stalnaker. But we need this in any case if the counterfactual analysis of dispositions is to be acceptable. Nozick's treatment of counterfactuals, for example, is such that $C \wedge E$ does not entail for $C \Box\!\!\rightarrow E$.

[6] It is worth noting that some (Broadbent 2007) working within a conditional approach to causation have begun to adopt that very view. Jennifer McKitrick in "Dispositions, Causes, and Reduction" (this volume) considers the possibility of a dispositional account of causation along the lines suggested above, and he problems that such an account would face.

law itself to distinguish between the two quantities as regards dispositional (causal or nomic) priority. In which case why should we not regard the force as a manifestation of the displacement, in which case displacement is characterized dispositionally: the displacement r between two points is the disposition whose manifestation, when masses m_1 and m_2 are located at the points, is a force between those masses with magnitude $F = Gm_1m_2/r^2$?

While I think this is along the right lines, it needs supplementation. There are two issues to be addressed. First, we need some explanation as to why it seems so much more natural to regard the force as a manifestation of the masses rather than of their displacement. Speaking figuratively we are inclined to think of the force as being generated by the masses, not by their displacement. Secondly, displacement crops up not just in the law of gravitation, but also in Coulomb's law and elsewhere. Thus it would appear that we could characterize displacement dispositionally with respect to a variety of different and seemingly independent manifestations. If so, then either (i) displacement is a multi-track disposition (one with more than one kind of manifestation); or (ii) one of these manifestations (e.g. gravitational rather than electric force) is privileged over the others.

2.1 Multi-track dispositions

The problem with regarding displacement as a multi-track disposition is that multi-track dispositions should not be regarded as fundamental. I shall here explain my reasons for thinking this. As we shall see, multi-track dispositions cannot have a pure dispositional essence. On the dispositional monist view of what properties are, that suffices to rule them out as fundamental. But there are more general reasons also. The intuitive idea is that if some property seems to be the conjunction of two dispositions, then that property does not look fundamental—since the conjuncts look more basic.

Multi-track dispositions (Ryle 1963: 114) have more than one kind of manifestation or stimulus, or both. A common view is that mental dispositions are often multi-track. To use Ryle's example, knowing French seems to be dispositional, but its manifestations may be various—talking French, writing French, obeying an order given in French, or even changing mental state when reading or hearing something in French. If we allow multiple manifestations, then we should allow multiple stimuli. For example, when discussing fragility it was clear that the manifestation is some kind of breaking, but it was less clear how to characterize the stimulus. One possibility is that fragility is a multi-track disposition with several different stimuli—striking, shaking, lateral stress (as would result in tearing). If we can have multiple manifestations and multiple stimuli, then we might have disposition-like properties with both multiple stimuli and multiple manifestations. Indeed the example of knowing French looks like this, since the stimuli are also various. They include not only external stimuli, such as hearing or reading something in French, but also internal stimuli, such as a desire to communicate with a Frenchman. It has been suggested that electric charge is a multi-track disposition. The manifestation of charge is a force on some other charge, its stimulus is the magnitude of that other charge. For different magnitudes of the other charge

(viz. different stimuli) a different force (viz. a different manifestation) is exerted.[7] Let us include among the multi-track dispositions all those which have multiple possible manifestations or multiple possible stimuli. Let us also call *complex* any disposition with either a logically complex stimulus or a logically complex manifestation.

Our first question is whether all multi-track dispositions can be regarded as equivalent to complex single-track dispositions; i.e. can the multiplicity involved in a multi-track disposition be accounted for simply by the logical complexity of the stimulus or manifestation? In the case of a multi-track disposition with single stimulus but multiple possible manifestations, the manifestations can be regarded as one disjunctive manifestation, and so we can easily assimilate this to the single-track case; similarly for multi-track disposition with a single manifestation but multiple stimuli. Matters are more complicated when it comes to multiple stimuli and multiple manifestations together. Typically these cannot be modelled by the single-track disposition with both a disjunctive stimulus and a disjunctive manifestation:

> D is the disposition to manifest $(\mathrm{M}_1 \vee \mathrm{M}_2 \vee \mathrm{M}_3 \vee \dots)$ in response to stimulus $(\mathrm{S}_1 \vee \mathrm{S}_2 \vee \mathrm{S}_3 \vee \dots)$

A disposition of which this characterization it true is one for which any of its possible stimuli could appropriately bring about any of its possible manifestations. That may hold for some multi-track dispositions, but it is clearly not correct for all. To the stimulus, 'Comment allez-vous?', the response, 'La plume de ma tante est dans my poche' is not a manifestation of knowing French, although it might be in response to some other stimulus, such as 'Où se-trouve la plume de votre tante?'. If charge is multi-track, then for a given stimulus (another charge at a certain distance) there is only one permitted manifestation.

Let us call a *pure* disposition one which can, in principle, be characterized in the way that D is above, viz. as a relation between a stimulus and a manifestation, even if these may be logically complex, i.e. can be characterized as 'the disposition to F when G' for possibly complex F and G. Knowing French and charge (on the view proposed) are not pure dispositions. However, they do look like conjunctions of pure dispositions. Consider, for illustrative purposes, the case of charge. Let x be a real number that will act as an index, and let q_x be a charge, r_x a displacement, and F_x a force, such that, for a fixed value of Q:

$$F_x = \epsilon \frac{Q q_x}{r_x^2}$$

Now consider, for some specific x the pure disposition D_x, whose stimulus is a charge q_x at a displacement r_x and whose manifestation is the exertion of a force F_x. Then an object with charge Q has this disposition. That object also has all the other parallel dispositions for other values of x. Let us assume that the indexing by x is such that all permissible combinations for values of q, r, and F are indexed by some x in the subset I of the reals. Then the impure disposition that the object has, its having the charge Q, will be equivalent to the conjunction $\bigwedge_{x \in I} \mathrm{D}_x$, that is the conjunction of the

[7] And charge may also be regarded as multi-track for the perhaps more decisive reason that a charged body is disposed to experience a lateral force when moving through a magnetic field.

D_x dispositions for all values of the index x.[8] It should be noted that a conjunction of simple pure dispositions is not in general equivalent to some complex pure disposition. Let us accept the conditional analysis of dispositions for sake of argument. A conjunction of counterfactuals is not in general equivalent to some single but complex counterfactual. That is, if S_1 and M_1 are counterfactually related, and S_2 and M_2 are also counterfactually related, there are not always any S_3 and M_3 satisfying:

$$(S_1 \Box\!\!\rightarrow M_1) \wedge (S_2 \Box\!\!\rightarrow M_2) \Leftrightarrow S_3 \Box\!\!\rightarrow M_3$$

Consequently, if $D_{(S_1,M_1)}$ and $D_{(S_2,M_2)}$ are distinct dispositional essences, we cannot expect there to be a dispositional essence equivalent to their conjunction. So we are unable to characterize the nature of the property in question in terms of *a* dispositional essence.

Thus if the conditional analysis were right, we typically cannot find a single pure disposition equivalent to a conjunction of pure dispositions.[9] Impure multi-track dispositions are typically irreducibly multi-track.

While it will be possible to gerrymander impure dispositions of all sorts, it is clear as regards the cases we are interested in, charge and knowing French, that the conjunctions are natural or non-accidental. It is my view that all impure dispositions are non-fundamental. Fundamental properties cannot be impure dispositions, since such dispositions are really conjunctions of pure dispositions, in which case it would be the conjuncts that are closer to being fundamental. However, pure dispositions may nonetheless be complex, and will include those pure multi-track dispositions with complex (disjunctive or conjunctive) manifestations. An interesting question is whether all complex dispositions, and multi-track dispositions in particular, are non-fundamental.

I'll consider four cases of complex dispositions: (i) simple (atomic) stimulus, conjunctive manifestation; (ii) disjunctive stimulus, simple manifestation; (iii) simple stimulus, disjunctive manifestation; (iv) conjunctive stimulus, simple manifestation. (i) A multi-track disposition with a simple stimulus but conjunctive manifestation is equivalent to the conjunction of dispositions each with the same stimulus but with different simple manifestations (each be the conjuncts in the original disposition). In which case it seems plausible to take the conjunctive disposition to be non-fundamental. (ii) Likewise, a disposition with a disjunctive stimulus is equivalent to a conjunction of dispositions each with a different simple stimulus corresponding to the disjuncts in the disjunctive stimulus. This is because the disjunctive stimulus says that the satisfaction of any of its disjuncts will bring about the manifestation, which is equivalent to possessing all of a set of dispositions with different simple stimuli. (iii) The case of

[8] It might be thought to be a disadvantageous departure from conventional wisdom (Armstrong, Lewis) to regard, for example, unit charge as a conjunction of properties rather than a single property. The disadvantage would be that this property is not a unity but a complex and so is less plausible as an inferred entity (assuming that that inferred entities are inferred in part on the basis of their ability to provided a unified explanation). My response is that although the conjunctive 'property' is not a unity it is *unified*. It is not an arbitrary conjunction, but rather there is an explanation of the conjunction. In this regard the 'property' of possessing unit charge is akin to a natural kind, in that the extension of the natural kind is not an arbitrary collection but is one that has a unified explanation. In note in passing that even Armstrong (1983: 111-116) faces a similar problem in accounting for functional laws.

[9] Although the conditional analysis is false there is nonetheless a sufficiently close relationship between dispositions and counterfactual conditionals that this argument remains decisive.

a disjunctive manifestation cannot be regarded as equivalent to any compound of simpler dispositions. Nonetheless, we would never need to posit such a disposition. Let the stimulus be S and the manifestation be $(M_1 \vee M_2)$. Thus we find on certain occasions S yielding M_1 while on other occasions S yields M_2. Thus we would have no reason to posit the multi-track disposition rather than two single-track dispositions. For example, if striking glasses with a particular force sometimes leads to breaking and on other occasions leads to a bell-like ping, then we do not need to posit a single disposition whose manifestation is (breaking or pinging); instead some glasses have the disposition to break which struck with that force, and others have the disposition to ping. (In this example one might prefer the single multi-track disposition if one thought that there was a single causal basis. But if we are considering fundamental dispositions, there will not be a (distinct) causal basis.) (iv) In the case of a conjunctive stimulus, there is no option other than to regard this as irreducible. Thus in two of the four cases we can simply replace the disposition by a conjunction of single-track dispositions. In the third case, we can posit multiple single-dispositions in place of the multi-track disposition. Only in the fourth case must the logically complex disposition remain. This is the case of the conjunctive stimulus. And although I have included this among the multi-track dispositions on the grounds of complexity, it is certainly not the sort of case that one has in mind when talking of multi-track dispositions, where it is typically the multiplicity of manifestations that one has in mind. One would most naturally say that this is rather a case of a single-track disposition with a compound (conjunctive) stimulus. Some multi-track dispositions might have complex stimuli and manifestations. By putting the manifestation in conjunctive normal form and the stimulus into disjunctive normal form, we can use (i) and (ii) to break it into a conjunction of dispositions with disjunctive manifestations and conjunctive stimuli. Then (iii) allows us to posit instead just dispositions with conjunctive stimuli and simple manifestations. In conclusion we do not need to posit fundamental dispositions with any greater complexity than conjunctive stimuli. Since conjunctive stimulus requires all its components to be instantiated, a disposition of kind (iv) (unlike those of kind (ii)) cannot be regarded as have a multiplicity of possible stimuli. Thus we do not need to posit fundamental multi-track dispositions.

Let us now return to the issue of whether spatio-temporal properties can be accommodated by the dispositional monist. The conclusion, that such properties, being multi-track, are not fundamental, is not itself inevitably problematic—it is not *a priori* that spatio-temporal properties and relations are fundamental. But it would mean that the debate is off. If they are not fundamental properties, then having dispositional essences or not does not directly bear on the truth of dispositional monism. As already remarked, it is the fundamental properties and relations that are held to be essentially dispositional. If it turns out that spatial separation is not a fundamental relation but supervenes on some other as yet unknown property or relation, then spatial separation provides no counterexample to dispositional monism and an investigation by inspection of whether the truly fundamental properties and relations are essentially dispositional must await further developments in physics.

The alternative is to regard one of the dispositions as privileged in characterizing the essence of displacement, and given the general theory of relativity it is natural to see gravitational force as participating in the essence of spatial properties and relations.

If we do take this view, the first question remains to be addressed. Why do we tend not to regard gravitational effects as *equally* the effect of displacement as of mass? This question is significant, because if we are right not to regard spatial displacement as causally efficacious (or more loosely as a potential agent) then displacement cannot be characterized with a dispositional essence.

2.2 Background structures and substantivalism versus relationalism

In order to respond to that question, we must take a short detour via our conceptions of space and time, in particular the view of the nature of space (and time) associated with the conception of spatial properties as causally inert. The classical conception of spacetime has been that of a stage or container within which things and laws act, but which is not itself involved in the action. It is a mere background. As such, although space and time are a part of the natural world, they are certainly not patients, that is to say recipients of effects, in any cause-and-effect relation, or more generally subject to change according to natural law. Their status as causes or agents of law-governed change is ambivalent. On the one hand, terms for spatial and temporal dimensions appear in the laws. On the other hand, we do not classically regard these terms as indicating action on the part of space and time. One reason for this is what Harvey Brown (Anandan and Brown 1995, Brown and Pooley 2006) among others calls the 'action–reaction' principle. Something can only be an agent if it is also a potential patient; something may only be a cause if is it also potentially the recipient of effects. Since on this view spacetime is a background *entity*, the displacement r between two objects is only indirectly a relation between them. It is primarily a relation between spacetime points. The objects inherit that relation by being located at spacetime points that are a distance r apart. On the classical view the structure of spacetime is fixed and unchanging. Since spacetime points do not change their relations with one another, it is difficult to see how they and their properties can contribute causally to the behaviour of objects located in spacetime. Thus the displacement r between spacetime points is inert, and so, in consequence, is the supervening displacement r between the objects.

In view of this the relationalist/non-substantivalist conception of spacetime ought to be more congenial to the dispositional monist. On the simplest version of this view spatial relations are directly relations between objects (not between spacetime points). This reverses the absolutist/substantivalist view according to which relations between object supervene on relations between spacetime points. The relationalist takes all the facts concerning space and time to supervene on facts about relations between objects. The laws of nature mention only spatial and temporal *relations* and these can be accounted for. They are at least in a position to obey the action–reaction principle, since spatial relations appear both as sources of change (e.g. in the gravitational law) and as as objects of change (as in Newton's second law). Since space and time just are the sum of spatial and temporal relations, and so there is nothing more to be explained than has been explained. While it hasn't yet been shown that spatial relations really are agents of change, the possibility is now open that they are.

The obvious problem with the simple relational view is that it fails to account for the full range of spatio-temporal possibility. There seem to be times and places where objects and events could be but are not. Hence Leibniz extends the set of relations to both actual and possible spatio-temporal relations. But then we must ask, what grounds such possibility? Furthermore the set of spatio-temporal relations is found to have a metric structure and we may ask for an explanation of that fact too. If spatial and temporal relations are fundamental, then we should expect them, according to a dispositional essentialist view of their essences, to generate the laws that underly the structure of spacetime, including facts about its metric.

In classical physics understood in an absolutist, substantivalist sense, however, this seems not to be the case. We have discussed that fact that laws such as Newton's law of gravitation and Coulomb's law *mention* spatial relations. These laws cannot be serious candidates for expressions of the essence of spatial relations since they tell us nothing about the structure of space. They tell us how the magnitudes of forces of certain kinds depend on spatial relations. But they do not tell us what spatial relations are possible and they do not tell us what metric the set of points in space possesses. It is telling that one response to this is conventionalism about spacetime, *à la* Poincaré, Schlick, or Duhem for example. According to views of this sort, a choice of geometry and metric is conventional. We typically choose our geometry in such a way as to make the laws of physics expressible in a convenient form. The choice does not reflect some fact concerning the real structure of space and time, there being no facts of that sort. While one is not obliged by classical physics to be a conventionalist about the geometry of space and time, the fact that conventionalism is an option shows that no laws in classical physics determine that geometry. Either way, whether one prefers Newtonian substantivalism or conventionalism, there is no room for laws of the sort (ones telling us about the structure of spacetime) that the dispositional essentialist about spatial and temporal properties seeks.

In summary the dilemma is this. The general problem in classical physics is that relationalism posits too little structure, not enough to explain empirically revealed aspects of space and time, while substantivalism posits too much, and in particular makes spacetime a background structure. Scientifically, there is a problem in not having enough structure—excess structure is preferable. From the metaphysical point of view (that of the dispositional monist at least) matters are reversed. The thinner commitments of relationalism are *prima facie* acceptable. If space is nothing but the spatial relations between objects, then we do have a law telling us how space changes, Newton's second law. On the other hand, if impelled by the requirements of physics to posit more structure, so that space is the fixed structure of spatial points, not the changeable structure of objects, then we have introduced a mere background that is not subject to any law. Such background structures of substantivalism, being inert, cannot be accommodated within the dispositional essentialist viewpoint.

2.3 Background-free physical theories

In a dispute between physicists and metaphysicians, it would be wise to take the side of the physicist. And so the preceding discussion might seem to put dispositional monism at a disadvantage. Recently, however, physicists such as John Baez (2001), Lee Smolin

(1991), and Carlo Rovelli (1997) have advocated the view that a good physical theory should be background-free. Thus either space and time should be eliminated from our theories (although an unlikely prospect, this is not impossible). Or they should be shown not to be merely background. Either way the grounds for spatial and temporal properties and relations being clear exceptions to dispositional monism would be removed—in the first case because the properties no longer figure in fundamental science at all, and so are not fundamental, natural properties; and in the second case because space and time would no longer be mere background but instead are fully fledged agents, capable of acting and being acted upon. This would permit spatial and temporal properties to be understood dispositionally.

It should be noted, however, that the motivation behind the drive for background-free physical theories is not exactly the same as that which seeks dispositional fundamental properties. In causal terms, the latter is concerned to show how space and time can be genuine causes. While spatial and temporal relations occur in physical laws, they seem, as presented classically, not to be entirely genuine causes. But the search for background-free theories is principally a matter of showing how space and time can be *affected* by other causes.

Let us put this a little more precisely. The dispositional essentialist wants the following to be true of any fundamental spatio-temporal property or relation P:

> P has a dispositional essence, viz. P can be characterized in terms of some stimulus and manifestation, S and M, such that it is essential to P that if Px, then (ceteris paribus) Sx $\Box\!\!\rightarrow$ Mx.

The problem is that although we may be able to find an entailed counterfactual for certain spatio-temporal properties, not every such conditional will reflect the essence of those properties. We have seen the general reason for this above. As Fine tells us, not every necessary truth is part of every essence: it is not part of your essence that you are accompanied by the number two. A specific case in point relevant conditionals arises because when the following is true:

> (A) Qx entails Sx $\Box\!\!\rightarrow$ Mx

it is typically also true that:[10]

> (B) Sx entails Qx $\Box\!\!\rightarrow$ Mx.

Thus if (A) shows us the essence of Q, it looks as if we have another entailment of a counterfactual, (B), which seems to indicate the essence of S. We should not exclude

[10] Typically, but not always. To see why consider this fallacious argument for the equivalence of ⟨Qx entails Sx $\Box\!\!\rightarrow$ Mx⟩ and ⟨Sx entails Qx $\Box\!\!\rightarrow$ Mx⟩.

> Assume that Qx entails Sx $\Box\!\!\rightarrow$ Mx. If so every Qx world is an Sx $\Box\!\!\rightarrow$ Mx world, and so every Qx and Sx world is an Mx world. Now consider any Sx. We must show that such a world is also a Qx $\Box\!\!\rightarrow$ Mx world. Consider the nearest Qx world. Such a world will be a world where both Sx and Qx. And we already have that all every Qx and Sx world is an Mx world. So this world is an Mx world. Hence every Sx world is a Qx $\Box\!\!\rightarrow$ Mx world.

The fallacy arises in assuming that the nearest Qx world to some Sx world is a world where Qx and Sx. But that need not be the case. In general it will not be the case where Qx and Sx are logically or metaphysically incompatible. Nor will it be true for Sx worlds where Sx and Qx are nomically incompatible. Such cases are, however, not pertinent to the issues currently under consideration.

the possibility that (A) and (B) both characterize the essences of Q and S respectively, in which case they are what Charlie Martin (Crane 1996: 135-6) calls 'reciprocal disposition partners'. Equally, for Fine's reasons, we should not assume automatically that (A) and (B) do both characterize the essences of Q and S. And in certain cases there seems to be an asymmetry; our initial problem was that the relationships between the various sources of force (mass, charge, etc.) and displacement seem to be examples of such an asymmetry.

I take it that something such as the following characterizes what is meant by a background:

> If K is a background structure in a theory T, then
>
> > (i) K is not subject to change and is not affected by changes elsewhere;
> > (ii) the laws of T refer to properties and relations of elements of K or properties and relations defined on K.

It is the first clause, in particular the phrase 'not affected by changes elsewhere' that characterizes the 'backness' as it were of the background.

The claim therefore that theories should be background-free, or that there is no background, is tantamount to saying:

> (B-F) in a true theory, any structure appearing in the laws of that theory is subject to being affected by changes elsewhere.

Thus, if L is a structure in a true theory T, then for certain stimuli S, the following is true:

> (C) S $\Box\!\!\rightarrow$ a change in L.

Does (C) help the dispositional monist, where L is spacetime? What the dispositional monist requires is a dispositional essence for spatial and temporal properties. If (C) provides that, then the essences of the spatio-temporal properties in question are such that under certain stimuli the structure of spacetime is itself changed. Now this is somewhat different from what we started looking for, which was spatio-temporal properties being responsible for changes rather than spacetime being the recipient of change. Nonetheless, (C) *could* do perfectly well in providing a dispositional essence. We may distinguish active and passive dispositions; active dispositions have manifestation in entities other than the possessor of the disposition, while passive dispositions have manifestations in the possessor of the disposition. Some favourite dispositions are passive, such as fragility.

However, in general the manifestation of a disposition should be of a kind such that it can itself be responsible for changes. Otherwise we would find that the properties in question are merely epiphenomenal. In the case of (C) that means that changes in L (here spacetime) must themselves be capable of being responsible for changes of certain kinds. If so, those dispositions may be the ones most appropriately regarded as the essences of spatio-temporal properties. Nonetheless, (C), even if it does not constitute a solution to our problem, can show how our concerns may be addressed. One reason

why it is difficult to see space and time as causes on a classical substantivalist conception, is that it is difficult to see them as in any way being effects. The background is unchanging. But if it is unchanging how can it generate any effects? On the other hand, if it is subject to change, then it is easier to see how it might itself be a cause of change. According to the action–reaction principle, something is a potential cause only if it is a potential effect also. Thus (C), which reflects the requirement of background-freedom, (B-F), tells us that spacetime and its properties may be affected by changes elsewhere; and the action–reaction principle tells us that since spacetime and its properties may be the recipients of change they may also be causes of it. In dispositional essentialist terms, we can see that by being potential manifestations of dispositional essences, spatial and temporal properties may also have dispositional essences themselves.

That perspective is precisely that endorsed by General Relativity. Each spacetime point is characterized by its dynamical properties, i.e. its disposition to affect the kinetic properties of an object at that point, captured in the gravitational field tensor at that point. The mass of each object is its disposition to change the curvature of spacetime, that is to change the dynamical properties of each spacetime point. Hence all the relevant explanatory properties in this set-up may be characterized dispositionally. And furthermore, this relationship helps address the second question raised above, by explaining why gravity is privileged over other forces in characterizing the essence of spatial relations.

3 Conclusion

If spatial and temporal properties and relations are fundamental natural properties and relations, then the dispositional monist must provide reasons for thinking, contrary to a common intuition, that they too have dispositional essences. One approach is to take a familiar geometrical property (such as triangularity) and show that its instantiation entails some counterfactual. But ultimately this turns out to be indecisive. The dispositional monist will expect dispositional essences to be reflected in the laws of nature. And since triangularity is not a fundamental property of the kind that appears in the laws of nature, strictly speaking it is irrelevant to the dispositional monist's argument, in that it is not the sort of example that would provide a counterexample to the claim that *fundamental* sparse properties are essentially dispositional.[11]

We looked therefore at the seemingly basic property of spatial separation and its relationship to the laws of nature. On a classical substantivalist conception of space, spatial separation is a relationship between points in an unchanging spatial background, and so incapable of acting as a cause, and so incapable of having a dispositional essence. A relationalist conception of space may seem more accommodating to dispositional monism, but was in the classical era scientifically problematic. Nonetheless contemporary physicists have resurrected relationalism in the form of the requirement that theories should be background-free. If that requirement is correct, then structures in true theories will not be mere backgrounds, but will be capable of being the recipients of effects. Add to that the action–reaction principle, then such structures, including

[11] On the other hand, a convincing argument that triangularity does have a dispositional essence would provide strong indirect evidence that the fundamental structural properties have dispositional essences also.

spacetime, become potential causes also. In the light of the action–reaction principle it is the fact that in classical physics space is a mere background that prevents us from being able to regard it as having a causal role and so prevents us from seeing it as having a dispositional essence. Thus it is the requirement of background-freedom that makes room for dispositional essences for spatial (and likewise temporal) properties and relations. And that space is occupied by the relationship between spatiotemporal properties and mass in General Relativity.

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