Persistence and Non-Supervenient Relations

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[ABSTRACT

I claim that, if persisting objects have temporal parts, then there are non-supervenient relations between those temporal parts. These are relations which are not determined by intrinsic properties of the temporal parts. I use the Kripke-Armstrong "rotating homogeneous disc" argument in order to establish this claim, and in doing so I defend and develop that argument. This involves a discussion of instantaneous velocity, and of the causes and effects of rotation. Finally, I compare alternative responses to the rotating disc argument, and consider the implications of my arguments for the doctrines of Humean Supervenience and unrestricted mereology.]

If persisting objects have temporal parts, then there are relations between the temporal parts of a single object which are not determined by the intrinsic properties of those temporal parts. The paper has three sections. First, I discuss the idea of non-supervenient relations. Second, I rehearse and defend the Kripke-Armstrong "homogeneous disc" argument which provides the main reason for believing in non-supervenient relations between temporal parts. Third, I consider other possible responses to the homogeneous disc argument, and argue that we should opt for non-supervenient relations.

1. Non-supervenient relations

Many relations are wholly determined by the intrinsic properties of the relata. Relative height is one of these: whether Jill is taller than Jack is wholly determined by their heights. Other relations seem at first not to be wholly determined by the intrinsic properties of the relata, but can in fact be analysed in terms of intrinsic properties once additional places in the relation are recognised. Whether Jill is more famous than Jack is not wholly determined by their intrinsic properties, but it seems likely that it *is* wholly determined by the intrinsic properties of Jill, Jack and the individual members of the relevant audience.

Other relations, however, are not wholly determined by the intrinsic properties of the relata, not even when we include "hidden" relata. The relation of being a certain distance apart is like this. The distance between Jill and Jack is not wholly determined by their intrinsic properties: there could be exact intrinsic replicas of Jill and Jack who were further apart. Their separation is not determined by purely intrinsic properties even if we take space-time points to be "hidden" relata, for Jill's being located at point P is not wholly determined by the intrinsic properties of Jill and of P. So facts about such spatio-temporal relations between objects are not determined by facts about the intrinsic properties of their relata: such relations are "non-supervenient".

Paul Teller suggests that non-supervenient relations of a different kind can explain otherwise mysterious connections between quantum objects. (Teller 1986 and 1989.) More-or-less simultaneous measurements on pairs of spatially separated photons give results which cannot be explained by the intrinsic states of the particles just before measurement. This might be evidence of a near-instantaneous causal connection between the intrinsic properties of the two photons. Teller, however, accounts for the correlations by positing a relation between the particles which is non-supervenient, in the sense explained above. Unlike the relation of separation, this is not a straightforward spatio-temporal relation, and in what follows I shall use the term "non-supervenient relation" to refer to non-spatio-temporal non-supervenient relations, like those Teller discusses.

I claim, on the basis of arguments given below, that there are non-supervenient relations between the temporal parts of persisting objects. This contradicts Humean Supervenience, the doctrine that "all there is to the world is a vast mosaic of local matters of particular fact, just one little thing and then another", together with spatio-temporal relations between these "local qualities" (Lewis 1986, pp. ix-x). I argue against Humean Supervenience. I will also argue, however, that rejection of Humean Supervenience is compatible with belief both in temporal parts and in unrestricted mereology, the doctrine that any two objects sum to make a third. This may comfort Humeans forced to give up their Supervenience.

2. The homogeneous disc argument

2.1. Exposition

Imagine a perfectly homogeneous disc, made of smooth stuff not atomistic matter.[1] For every moment, record all the information about the state of the world at that moment, but without recording information about relations between objects which are wholly present at different moments. Call this record the "holographic representation" of the world.[2] Now, the holographic representation will reveal that at every moment there is a homogeneous disc in a particular spot, but it will not reveal whether that disc is rotating about a vertical axis through its centre. Yet its rate of rotation is an intrinsic property of the disc. So the persisting disc has an intrinsic property which is not determined by the intrinsic properties of its temporal parts.[3]

I claim that the best response to this homogeneous disc argument is to accept that, if persisting objects have temporal parts, then persisting objects have properties which are determined by non-supervenient relations between their temporal parts. There are other possible responses to the argument, and I shall discuss these in the third section of this paper. Before doing so, however, I need to defend the homogeneous disc argument against various objections.

2.2. The no-difference objection

The argument supposes that there are two possible worlds, discernible only in that one contains a rotating homogeneous disc, whilst the other contains a stationary homogeneous disc. The argument is that a certain kind of record, a "holographic representation", could not capture the difference between these two possible worlds. The holographic representation records all and only the information about the world

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[1] The argument is published in Armstrong (1980) and was the subject of lectures by both Kripke and Armstrong during the 1970s.

[2] The term "holographic" is supposed merely to indicate the richness of the representation; no closer analogy to real holograms is intended.

[3] Perhaps its rate of rotation is not an intrinsic property of the disc, but a matter of the spatio-temporal relations between its spatial parts and other physical objects, or space-time points. Nevertheless, rate of rotation is not captured by the holographic representation, for it is not determined by the intrinsic properties of the temporal parts of these spatial parts, together with their relations to their contemporaries.

as it is at every moment, without recording information about relations between objects existing at different moments.

The no-difference objection to the homogeneous disc argument is the claim that, contrary to supposition, there *is* no difference between these two possible discs, and thus, *a fortiori*, there is no difference which goes uncaptured by the holographic representation. The claim is not that both discs are stationary, for it would be arbitrary to pick out zero as the common value of angular velocity. Rather, the claim must be that, for a homogeneous disc in such circumstances, there can be *no fact of the matter* as to whether it is rotating.

If there is no fact of the matter about whether a given disc is rotating, then there is no fact of the matter about what would have happened if someone had touched the disc, or had splashed paint onto it. For each disc, it is true that if someone had measured the angular velocity of the disc, then she would have obtained some determinate result. But in neither case is there some determinate result that would have been obtained had someone measured the angular velocity of the disc. The result of any possible measurement of angular velocity is undetermined.

The same goes for counterfactual measurements of indeterministically evolving quantities. (See Redhead 1987, pp. 92-5.) Wearing green trousers, I record the determinate time, t_1, at which an atom indeterministically decays. If I had performed the experiment in red trousers, I would also have obtained a determinate result, but there is no fact of the matter as to what it would have been, despite the apparent irrelevancy of my trousers. The class of possible worlds indiscernible up until t_1 from the actual world, except in the matter of my trousers, contains worlds in which the atom decays at t_1, but also worlds in which it does not. The time of decay is an indeterministic matter, so nothing which happens before t_1 makes the atom decay at t_1 or prevents it from decaying at t_1.

Where there is indeterminism, such indeterminacy about counterfactual measurements is unmysterious. But what of the discs? The no-difference objection supposes that, for any homogeneous disc, a measurement of angular velocity *would* give a determinate

result, but that there is no fact of the matter as to what that result would be. Yet neither rotation nor measurement of the disc is supposed to be an indeterministic process. This indeterminacy is rather peculiar, to say the least.

Moreover, the no-difference objector must allow that if the disc *had* been measured, then it *would have had* a determinate angular velocity, even before the measurement. If she denies this back-tracking counterfactual, and supposes that measurement would have created new determinacy, then she produces a bizarre classical analogue of the quantum measurement problem. So whether a homogeneous disc has a determinate rate of rotation at a given moment counterfactually depends upon whether that rate is measured at any time in the future. Recall that, in this context, a "measurement" need not involve any conscious observer, or special apparatus. Any event which makes the disc slightly inhomogeneous—the landing of a speck of dust on the disc, for example—would give the disc a determinate rate of rotation for all time.

I have been considering this strange indeterminacy for the disc, but matters are even worse for wedges or segments of the disc. A segment has determinate rotation or rest if and only if the others do too. Whether or not a particular segment has a rate of rotation at all, whether or not there is a fact of the matter as to where that segment is in the future, depends upon whether the rate of rotation of any *other* segment is measured, upon whether a speck of dust ever falls upon another segment.

I conclude that anyone tempted to deny that there is no difference between the two discs can only be imagining, mistakenly, that both discs would then be at rest. Once we see that "no difference" means that the discs have no determinate rate of rotation, we see that this position is untenable. Anyone who hopes to defeat the homogeneous disc argument should look elsewhere.

2.3. Holographic difference objections

The homogeneous disc argument attempts to show that there can be differences between worlds without differences in their holographic representations. I have just rejected the suggestion that there is no real difference between the two worlds in question. The second type of objection is that there *is* a difference between their

holographic representations after all. I will consider, in turn, the suggestions that the representations can capture differences in angular velocity, differences in causes of rotation, and differences in effects of rotation between the two discs.

2.3.1. Differences in angular velocity

The difference in angular velocity between the two discs allegedly goes unregistered by the holographic representations, but why not simply include instantaneous angular velocities in the representations?[4] The holographic representation, as I defined it, includes all and only those facts which can be recorded without recording facts about relations between objects wholly existing at different times. Can't we include the instantaneous velocity of a disc-segment without entailing anything about objects existing at other moments?

Prima facie, angular velocity is excluded from the holographic representation on the following grounds. To say that something is stationary, for example, is to say that at the next moment it will be in the same place. To say that a disc-segment is rotating at a certain rate is to say something about where it will be at future moments. Wesley Salmon cautions us that

> [i]t is important to note...that this notion [of instantaneous velocity] is defined by a limit process, so the value of the velocity at an instant depends logically upon what happens at neighboring instants...Although instantaneous velocity does characterize motion at an instant, it does so by means of implicit reference to what goes on at neighboring times. (Salmon 1970, p. 24.)

To include angular velocity in the holographic representation is to deny Salmon's claim that attributions of velocity involve "implicit reference to what goes on at neighboring times". There are two main motivations for denying Salmon's claim, but I shall argue that neither is compelling. The first concerns Zeno-type paradoxes, the worry that if we cannot attribute instantaneous velocity to objects considered as they are at a moment, then we cannot explain how motion is possible. The second thought is that the possession of a certain instantaneous angular velocity by a segment at a

[4] Dean Zimmerman's discussion of this issue is both detailed and helpful. (Zimmerman 1998.)

moment does not entail anything *specific* about objects at other times, for there may be all sorts of accelerations and forces at play. To say that something has zero velocity is to say only that it will be in the same position a moment later *if* no net forces act upon it. I shall deal in turn with these motivations for including instantaneous angular velocity in the holographic representation.

The Zeno worry is as follows. We must be able to attribute instantaneous velocity to objects regardless of what goes on at other times, else we could never distinguish between stationary and moving objects, which would be absurd. I agree that this would be absurd, but I *can* distinguish stationary from moving objects: I allow that we *can* attribute instantaneous velocity to objects, and I certainly do not claim that things are always instantaneously at rest. The existence of instantaneous angular velocity is not at question here, merely its admissibility to the holographic representation.

Perhaps this seems disingenuous. After all, I claim that to attribute angular velocity to a disc-segment at a moment is to say something about other times. Were a temporal part of the segment not surrounded before-and-after by other temporal parts, then there would be no fact of the matter as to whether it was rotating. But this does not entail that "really" the temporal part has no determinate rate of rotation when it *is* surrounded by other temporal parts. Were this table-leg not appropriately connected to other legs and to a table-top, it would not be part of a table. But this does not entail that "really" the leg is not part of a table when it *is* thus connected. To think otherwise is mere prejudice against relations, a prejudice which begs the question in this context. My claim that velocity is a matter of relations between objects existing at different times does not downgrade or ignore velocity. Nor does it entail that everything has an instantaneous velocity of zero.

The second argument for including angular velocity in the holographic representation runs as follows. We cannot identify an instantaneous angular velocity with its effects on displacement, since these effects will depend upon whether any net forces are acting. An instantaneous velocity, angular or linear, is like a disposition, which

produces different behaviour under different circumstances. We should not mistake the disposition for its particular, contingent display.

I agree that there is both less and more to instantaneous angular velocity than the actual spatio-temporal relations between successive temporal parts. Less, because these relations are a function of applied forces as well as initial velocity. More, because the instantaneous angular velocity also grounds counterfactual conditionals of the form "if a net force **F** had been applied to the disc then....". But these conditionals concern what goes on at other times, even if they say nothing *categorical*. Classical mechanics is the device we use for establishing such conditionals, which relate locations at different times to net forces applied, given initial velocity.

We can spell this out further. Take a particular temporal part of a disc-segment. The positions of various future temporal parts depend upon the position of that initial part, in a way conditioned by net forces acting and by the initial velocity. To attribute instantaneous velocity is to say something partial and conditional about certain future temporal parts, and not about others. It is to say something about the future states of a persisting object, about how these will vary according to the forces which apply.

Neither the Zeno worry nor the dispositional nature of velocity gives us reason to suppose that instantaneous angular velocity is admissible to the holographic representation. To specify the angular velocity of a segment at a moment is to entail something about what goes on at other times, albeit something conditional, and thus to break the rules of holographic representation.

2.3.2. Differences in causes of rotation

There are, however, other ways of differentiating the holographic representation of the spinning-disc world from that of the stationary-disc world, by including either the causes or the effects of rotation. Both Harold Noonan and Denis Robinson remark that there must have been some cause of the difference between the two discs. (Noonan 1988, p. 96, and Robinson 1989, p. 405-6.) This interaction between the disc

and some other object could be included in the holographic representation and could thus distinguish the representations of the two worlds.

There are two things to be explained: that each disc has a determinate rate of rotation, and that they have different rates of rotation. The latter may be explained by the fact that one disc was shoved when the other was not, *provided* we can assume that before the shove both discs had some determinate angular velocity. Shoving and dampening do not cause rotation or rest *per se*, just changes in rate of rotation.

What, in the holographic representation, can explain the determinacy of the pre-shove state? It cannot be the subsequent shove, since only one of the two discs is shoved.[5] Ultimately, something about the way in which the discs first came into existence must have made their initial angular velocity determinate, and thus amenable to change by subsequent applied forces. So to be effective, the objection from causes must be that a homogeneous disc *could not* simply appear, or always have existed, but must rather have been produced by some holographically recordable process which determined its initial angular velocity.

Understanding the real form of the objection from causes makes it less plausible. It may seem obvious that if one disc were not given a distinguishing shove, then the two discs would have the same angular velocity. It is less obvious that, as the objector from causes must claim, a homogeneous disc could not simply appear or always have existed. But let us accept the objection, and suppose that there must have been some holographically recordable aspect of the production of the discs which gave them *determinate* initial angular velocities, and some simultaneous or subsequent difference in applied forces which gave them *different* angular velocities.

So the two worlds have different holographic representations. Nevertheless, there are facts about these worlds which go uncaptured even by these enriched holographic representations: we cannot identify the difference between the discs with the cause of that difference. Robinson makes a similar point, noting that, if we suppose everything

[5] And recall my earlier objections to the idea that earlier velocity is made determinate by later measurement.

to be captured in the holographic representation, then we must suppose that the result of any later measurement of angular velocity would be a direct causal consequence of the initial shove, since there are no intervening differences between the two discs. He calls this "action at a (temporal) distance" (Robinson 1989, p. 406), and we should note that it is peculiarly unattractive to the proponent of Humean Supervenience.

"Initial shove" differences do not capture the full difference between rotating and stationary discs. They make a historical difference between the discs at any moment, and a difference in counterfactual measurement results, but they leave an explanatory gap, since the former cannot explain the latter in any unmysterious way.

In contrast, non-supervenient relations between the temporal parts of a persisting segment *can* explain how the results of any measurement performed on the disc now are a direct consequence of the present state of the disc, not of its historical properties. The successive temporal parts of a segment stand in non-spatio-temporal non-supervenient relations to one another. In conjunction with applied forces, spatio-temporal relations between these "specially related" temporal parts—and not those between other temporal parts—determine the rate of rotation of the segment and thus the disc. So far as the holographic representation tells us, there are no present differences between the discs at any moment, but there are relational differences which do not show up in the representation. These differences are direct causes and explanations of the actual and counterfactual differences in measurement results. I can feel the disc moving because the temporal part I am touching is specially related to an earlier temporal part which was elsewhere, rather than to one which was here.

Teller introduced non-supervenient relations between distant elements of a quantum system instead of positing mysterious causal influences between these elements. Such influences would be mysterious principally because they appear to travel faster than light. Direct causal connections between the initial shove and the present measurement of rotation would not be mysterious in this respect. But there is a second, lesser mystery in the quantum case: any causal influence between the distant elements of the system appears to be transmitted directly, without any intervening disturbance. This mystery has a direct parallel in the homogeneous disc: if the

holographic representation is complete, there is a direct causal influence between the initial shove and the later measurement result, without any intervening differences between the rotating and the stationary discs. Non-supervenient relations provide the required intervening differences.

The objection from causes is less plausible than it seemed, since it must suppose that differences in the holographic representation can explain why the discs have any determinate rate of rotation at all, as well as the difference in their rates of rotation. But even if we accept that there are such differences between the holographic representations of the two worlds, these alone cannot explain the direct consequences of, for example, touching the discs. I have shown how non-supervenient relations can be of assistance here.

2.3.3. Differences in effects of rotation

I am considering possible objections to the homogeneous disc argument, objections which attempt to differentiate between the two holographic representations. I have dismissed the suggestion that angular velocity be included in the representation, and I have limited the role of initial causes. Finally I want to consider differences in the holographic representations brought about by the effects, rather than the causes, of the rotational differences between the two discs.

There are differences between rotating and stationary objects. If the coffee in a cup is rotating, it has a concave surface; stationary coffee is flat. Such differences in shape are admissible to the holographic representation, and might seem to distinguish the rotating from the stationary coffee without any need for non-supervenient relations or the like (although it is by no means clear that such convenient differences are available for all homogeneous objects.[6])

Does this show that we need not posit non-supervenient relations between temporal parts? I might respond, as Kripke might, that there is nothing inconceivable about a stationary cup of coffee with a concave surface, nor, indeed, about rotating coffee

with a flat surface. The difference between concavity and flatness happens to be correlated with the difference between rotation and rest, but this is a contingent matter, and should not be taken as constitutive of the difference between rotation and rest. Rate of rotation is not captured by the holographic representation.

The adequacy of this response hinges upon the value of considering worlds unlike our own. In our world, concavity and rotation go along together: need we be concerned about possible worlds in which they come apart? I skirted a similar question above, when I agreed that we need not be concerned about perpetually existing or instantaneously created discs. More simply, we might question the relevance of stories about homogeneous discs to our actual atomistic world. The more we focus upon possible worlds very like our own, the less successful the homogeneous disc argument seems, and thus the less compelling non-supervenient relations may seem.

The defender of Humean Supervenience against non-supervenient relations cannot take this "actualist" line, however. David Lewis acknowledges that the quantum situations Teller discusses may provide an empirical refutation of Humean Supervenience, but announces his determination to defend Humean Supervenience from attempted philosophical, or *a priori*, refutations. (Lewis 1986, p. xi and 1994, p. 474.) It would seem a little *ad hoc* to invoke empirical considerations when they favour Humean Supervenience, whilst ignoring those which undermine the doctrine.

Explanatory considerations provide another reason to take notice of other possible worlds, and to avoid identifying rotation with its causes and effects. Otherwise, as we saw above, we are unable to explain those effects, except by imagining that the result of measurement today is a direct causal consequence of a shove many years ago. Part of what we hope for from a *measurement* result is that it be correlated with some present feature of the object measured.

There is a third reason for acknowledging worlds in which rotating coffee is flat, worlds in which discs appear out of thin air, or worlds in which there are

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[6]For example, in earlier drafts I discussed a sphere which bulges to become oblate when rotating. However, I have been reminded that the holographic representation cannot distinguish between a

homogeneous discs. Although these worlds differ from our own in various ways, they are nevertheless worlds in which there is rotation and rest. The "coffee" world is odd precisely because coffee *rotates* there without becoming concave. Similarly, an object's being atomistic is not a pre-condition of its rotating, and a disc's origins do not, in general, affect whether it can have a determinate rotation.

So these worlds are relevant to our discussion of rotation. An atomistic disc rotates in the same way as a smooth disc, although rotation is more easily detected in the former case, if we have a powerful microscope to hand. If we agree that rotation is not determined by intrinsic properties of temporal parts in non-atomistic worlds, then we should also accept this for our own world.

3. Conclusion and alternative conclusions

The homogeneous disc argument is powerful, and is relevant to the actual world. In this final section I want to show how non-supervenient relations can explain the phenomena highlighted by the homogeneous disc argument. I will also argue that these relations provide the best explanation, better than a range of alternatives.

I claim that there are relations between the distinct temporal parts of a single persisting object which are not determined by the intrinsic properties of those temporal parts. What motivates my claim? Opting for non-supervenient relations is the natural "least move" in response to the homogeneous disc argument, since the holographic representation captures exactly those properties of the temporal parts which underdetermine these relations. Differently described, non-supervenient relations are properties of the persisting object itself, properties which do not supervene upon the intrinsic properties of its parts.

Collections of temporal parts which form a single object are distinguished from other collections as follows. The state of a later part depends, counterfactually and causally, upon the state of earlier parts, in a way in which it does not depend upon parts of other objects. Non-supervenient relations ground these dependencies. Seeing this

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bulging rotating sphere and a stationary oblate object.

allows us to spell out the connection between the rate of rotation of the disc and the persistence of its segments. Any given temporal part of a disc segment is linked by special relations to some later temporal parts, and not thus linked to others. If a temporal part is thus linked to temporal parts in the same place at later moments, the disc is at rest; if it is not, the disc is rotating.[7]

We saw earlier that an instantaneous velocity does not guarantee any later position, but that it entails certain conditionals about the relation of later position to applied net forces. I talked of an instantaneous velocity as a disposition of a persisting object, one which could be displayed in different ways under different conditions. We can now see non-supervenient relations between temporal parts as grounding these dispositions, by determining *which* later temporal part is conditionally dependent upon the position and velocity of a given earlier part. In short, I claim, non-supervenient relations account admirably for the phenomena highlighted by the homogeneous disc argument.

I shall now compare and reject some alternative responses to the homogeneous disc. Why, for example, have I insisted upon non-supervenient relations, instead of merely saying that there are causal relations between the different temporal parts of a persisting object? I agree that there are "special" causal relations between the earlier and later parts of a persisting object, but I claim that non-supervenient relations are needed in order to account for these. Consider, for example, some standard accounts of causation.[8]

Regularity theorists claim that causation is nothing more than constant conjunction, in this case that the state of an earlier temporal part causes that of a later temporal part if and only if there is a regular correlation between states of these types. But our central problem is that, so far as intrinsic properties go, there *is* no correlation between the earlier and later parts of a particular segment which does not also hold between any "random" pair of temporal parts of segments. We accepted this when we accepted that rate of rotation was not captured by the holographic description.

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[7] Of course this gloss is schematic: a rotating segment returns to the same place once in every revolution.

The same problem arises for universals-based accounts of causation, at the other end of the metaphysical spectrum. Without non-supervenient relations, there are no universals exemplified by pairs of temporal parts of a single segment that are not also exemplified by "random" pairs of temporal parts.

Counterfactual accounts of causation say that a causal connection simply is the counterfactuals it appears to ground. One advantage of non-supervenient relations is that they relieve any discomfort we may feel at the thought of "bare" counterfactuals, grounded in no regularity or property of the object in question.[9] Furthermore, taking the "special connection" between temporal parts of a single object to be a matter of counterfactual dependence seems to get things the wrong way round. The later part depends for its state upon that of the earlier *because* they are parts of the same object; because, according to me, they stand in a non-supervenient relation to one another.

Merely invoking causal relations does not account for the homogeneous disc. A different response to the homogeneous disc argument is to adopt Denis Robinson's notion of "second-order quasi-qualities having the character of vectors". (Robinson 1989, p. 406.) These qualities guide the propagation of ordinary first-order qualities, yet they are intrinsic properties of temporal parts, and are thus eligible for inclusion in the holographic representation. This differs from the suggestion that we include instantaneous angular velocity in the holographic representation. Robinson's qualities expand the holographic representation, supposedly filling the explanatory role I reserved for non-supervenient relations.

Douglas Ehring has a powerful objection to Robinson. (Ehring 1997, pp. 111-2.) He considers a homogeneous disc which rotates indeterministically: its velocity and position at one moment are underdetermined by its previous velocity and position, and by applied forces. Then the actual velocity of the disc, the question of where a given segment is from one moment to the next, is underdetermined by Robinson's vector qualities, which have only a probabilistic influence on these quantities. Yet the

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[8] Zimmerman investigates the possibilities here. (Zimmerman 1998.)
[9] Noonan feels this discomfort. (Noonan 1988, p. 97.)

disc still has a determinate angular velocity. So there is a further fact of the matter about velocity, over and above the vector qualities.

The indeterminism scenario distinguishes velocity from its causes, by supposing it to have an uncaused element. Robinson attempts to capture velocity by attributing extra intrinsic properties to temporal parts, but at most these can capture the causes of velocity. Non-supervenient relations, on the other hand, escape Ehring's criticism. If a homogeneous disc were moving indeterminstically, non-supervenient relations would still hold between earlier and later parts of a single segment, and not between "random" pairs of temporal parts. These relations would ground probabilistic conditionals relating the earlier and later parts, just as they ground non-probabilistic conditionals in the deterministic case.

As we have seen, it is the intimate connection between earlier and later parts which explains measurement results whilst escaping objections from indeterminism. This may suggest the closest connection of all, that of identity. Perhaps the segment has no temporal parts. This is certainly a possible response to the homogeneous disc argument, but not one we are forced to adopt. If objects have temporal parts, then those parts stand in non-supervenient relations to one another, but this is not to say that those parts are identical, either "wholly" or "partly". Moreover, I believe, there are independent reasons for accepting temporal parts, based on considerations about changing properties, about fission and fusion, and about degrees of persistence.

Non-supervenient relations provide an alternative both to belief in Humean Supervenience, and to scepticism about of temporal parts. It is perfectly possible to believe in temporal parts whilst rejecting Humean Supervenience.[10] Just as Teller's non-supervenient relations give an unmysterious sense to "holism" in quantum mechanics, my use of non-supervenient relations provides an unmysterious sense in

[10] Sally Haslanger argues convincingly that the doctrine of Humean Supervenience does not entail that objects have temporal parts. (Haslanger 1994.) I have tried to show that the *failure* of Humean Supervenience does not entail that objects do *not* have temporal parts. If I have succeeded, then the link between Humean Supervenience and theories of persistence is broken.

which different temporal parts of a single object are connected without being identical.[11]

Finally, what of unrestricted mereology? This doctrine, that any two objects make up a third, is often associated with a belief in temporal parts. The joint consequence is that every collection of temporal parts composes an object, and thus that there are very many persisting objects, only a small fraction of which are "recognised" by us. How do non-supervenient relations affect this picture?

One might suppose that non-supervenient relations conflicted with unrestricted mereology, since they privilege some collections of temporal parts over others. Indeed, this privileging role is what enables the relations to ground rotation and displacement. Nevertheless, the recognition that some collections of temporal parts are distinctive has no consequences for the question of whether other collections exist, or have a sum. Non-supervenient relations make everyday persisting objects objectively "special" and this spells defeat for the hypothetical philosopher who supposes that we "recognise" a purely arbitrary subset of the persisting objects. Nothing we have seen here, however, entails that only the special objects exist, and nothing here entails that unrestricted mereology must be abandoned.[12]

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[11] Ehring's response to the homogeneous disc argument is to suppose that tropes persist without having temporal parts, and that this grounds rotation and so forth. Like scepticism about temporal parts of physical objects, Ehring's response is not forced upon us by the homogeneous disc. (Ehring 1997.)

[12] Thanks to the graduate philosophy seminar in Cambridge, and also to James Ladyman, Peter Lipton, Jonathan Lowe and Hugh Mellor.

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