

Humean Supervenience and Rotating Homogeneous Matter

CRAIG CALLENDER

Humean supervenience (HS) is the thesis that everything supervenes upon the spatiotemporal distribution of local intrinsic qualities. A recent threat to HS, originating in thought experiments by Armstrong and Kripke, claims that the mere possibility of rotating homogeneous discs proves HS false. I argue that the rotating disc argument (RDA) fails. If I am right, Humeans needn't abandon or alter HS to make sense of rotating homogeneous discs. Homogeneous discs, as necessarily understood by RDA, are not the sorts of things in which we should believe. These discs do not belong in our ontology—not because there is a problem with their homogeneity, but (surprisingly) because there is a problem with their rotation. RDA is shown to be a kind of parody of classic arguments for spatial substantivalism.

Humean supervenience (HS) is the widely discussed thesis that everything supervenes upon the spatiotemporal distribution of local intrinsic qualities. David Lewis, the most prominent advocate of HS, admits that HS may be proven false by empirical results, but he is adamant that it not be proven wrong by a priori philosophical reflection (1986, 1994). To this end Lewis and others have spilt much ink discussing troublemakers for HS such as chance and laws of nature. However, one much-discussed troublemaker for HS has to date been mostly ignored by the Humean camp. The argument, originating in thought experiments by Armstrong and Kripke, claims that the possibility of rotating homogeneous discs alone wrecks the HS programme.¹ If correct, Humeans must either abandon HS or reformulate it to include a larger subvenient base set of properties, one that includes properties perhaps unpalatable to Humean tastes.

There has been scarcely a peep in response to these arguments from the Humean community.² What explains the silence? Perhaps the

¹ See Armstrong 1980, Kripke (1979 APA, Eastern Division, and elsewhere), Shoemaker 1984, Robinson 1989, Zimmerman 1998 and Hawley 1999. Zimmerman shows that C. D. Broad discussed the same idea well before Armstrong or Kripke. Whether the homogeneous matter is shaped into rivers, discs, or spheres varies with author. As the differences play no role, for the sake of uniformity I will confine myself throughout to discs rotating about their symmetry axes. Because Kripke's paper is unpublished, I will not discuss his particular stance on the argument.

² Lewis briefly discusses this argument and appears to concede some ground to it in Lewis 1986,

Humean lacks a decent reply. Or more likely, the apparent obviousness of the reply causes the silence. The natural response is to remind advocates of the rotating disc argument (RDA) that HS is a contingent thesis, and since we don't have rotating homogeneous discs in our world, the objection is irrelevant to HS.

Recent defenders of RDA are not impressed with this (anticipated) response. They are probably right not to be. Is it so clear that homogeneous objects—that is, atom-less objects of uniform composition—do not live in worlds like ours, the so-called 'inner sphere' of possibility? Certainly scientists have on a number of occasions judged our world to be populated with fundamental atoms that are homogeneous and spatially extended. Humeans not wanting to shrink the volume of the 'inner sphere of possibility' uncomfortably close to the actual world ought not dismiss this threat lightly. If RDA is a good argument, its conclusion is damaging to HS.

Fortunately for Humeans, the argument is no good. If I am right, Humeans needn't banish homogeneous rotating discs from the 'inner sphere' of possibility. For all the argument shows, Humeans may even 'allow' homogeneous matter to exist in the actual world. However, homogeneous rotating discs, *as understood by RDA*, clearly do not live in worlds remotely like ours. *These* discs are the metaphysical equivalent of fairies, ghosts, and vital spirits. Humeans and non-Humeans alike should deny their existence—not because there is a problem with the disc's homogeneity, but (surprisingly) because there is a problem with their rotation. As we shall see, RDA is a kind of parody of classic arguments of spatial substantivalism.

1. The argument

HS is the thesis that everything in the world supervenes upon what we might call the 'Humean basis'. The Humean basis consists of intrinsic locally instantiated qualities and external spatio-temporal relations between spacetime points. There is no difference anywhere without a difference in the arrangement of qualities. Everything not itself in the Humean basis supervenes upon it. To be made precise, HS needs to answer many questions. What are natural properties? What are intrinsic properties? Does 'instantiation at a point' preclude vectorial quantities, such as velocities, which lie on tangent planes to surfaces? How is HS to be modified in the face of quantum nonlocality? Why

p. xiii and 1994, p. 475. In Lewis 1999 he advocates fixing HS along the lines suggested by Robinson 1989 (see below).

be Humean in the first place? We will not tackle these questions here, except where they are relevant to RDA; however, answers to some of these questions are discussed in the literature.³

RDA claims that neither the Humean basis or properties supervenient upon the Humean basis can distinguish a rotating from a stationary homogeneous disc. Since, *ex hypothesi*, there is a difference between the two, HS fails to account for a significant difference between the two discs. Robinson puts it as follows:

Suppose for instance that we are comparing two worlds, in all other respects just alike in their distribution of qualities, one of which contains a stationary disc of homogeneous matter, while the other contains an exactly similar disc which rotates... Then it seems that the arrangement of qualities in the two worlds will be identical. *Ex hypothesi* the worlds differ, so that whether we locate the difference at the level of identity or of causation or of counterfactuals, we seem still to have a counter-example to HS (Robinson 1989, p. 402).

The reasoning is as follows. The disc consists of perfectly smooth, homogeneous, and therefore, non-atomistic stuff. Because it is not composed of atoms, we cannot trace out their four-dimensional worldlines to inspect whether a disc is rotating, i.e., whether their worldlines trace out a helical ‘corkscrew’ shape or not. Since the discs are perfectly alike, we cannot paint one spatial part red and follow its worldline. And crucially, because they are homogeneous, one spatial part at one time is as similar to another spatial part at a later time as to any other spatial part at that time. The Humean, as a consequence, cannot appeal to her familiar resources of similarity/continuity in order to identify spatial parts across time (and thereby determine rotation or non-rotation). Consequently, the disc’s (non-)rotation doesn’t supervene upon the Humean basis, in violation of HS.

A presupposition of this argument—one that we’ll return to later—is that we ought to be able to distinguish these two possibilities. One reason for thinking this is that we can conceive of homogeneous discs rotating and remaining stationary, so this seems like a possibility, perhaps one worth making sense of in our metaphysics. If this sort of motivation isn’t enough for you, it can be bolstered with various intuition pumps. These aren’t provided by any of the proponents of the arguments, but it isn’t hard to arrive at some.

- (1) Consider a disc that is completely homogeneous except for 20 red polka dots scattered along its side. Initially still, it starts to

³ Loewer 1996 contains a sophisticated articulation of HS. Maudlin 1996 criticises the motivations for believing HS.

spin. We see this by watching the polka dots go by. Measuring the rate at which they are rotating, we determine that the disc is rotating at 100 m.p.h. A strong wind is blowing, however, and it gradually strips the disc of its dots. This does not affect the rate at which it spins — 3, 4, 5 ... dots fall off and the remaining ones are still rotating at 100 m.p.h. This process continues: 19 dots have fallen off, and still the disc's velocity is 100 m.p.h. When the 20th dot falls, surely the disc is still rotating? Surely it didn't come to a grinding halt, from 100 m.p.h. to 0 m.p.h. in an instant? We therefore can have good reason to believe rotating homogeneous matter is possible.

- (2) Suppose two machines, *A* and *B*, produce homogeneous discs at a rate of one per day. When we place objects on the discs produced by *A* they rotate around a point at the centre of the disc; when objects are placed on the discs produced by *B* they remain still. This has happened reliably, let's suppose, for 500 years. Now today the machines have ejected their discs. Before we place an object on either, doesn't the mountain of inductive evidence make it reasonable for us to claim that the homogeneous disc from *A* is rotating and the homogeneous disc from *B* is not? We therefore can have good reason to believe in the two possibilities motivating RDA.⁴

Papers defending RDA have not tried to motivate the argument as I just have, nor do they describe the details of the possible worlds more than as above. Instead, after some methodological contemplation, most authors propose an entity deemed necessary to distinguish rotation from non-rotation. Mostly these entities are non-Humean in nature, though some are perhaps more congenial to Humeanism than others. Lewis (Lewis 1999) sees the addition of vector fields to the Humean basis as a necessary ingredient for the tenability of HS, not merely because of RDA, but also for other matters, e.g., handling electromagnetism. Both Robinson (Robinson 1989) and Lewis clearly view such a fix as 'Humean' in spirit. Perhaps they are right. In any case, I won't waste time quibbling about the honorific 'Humean'. The divide between previous commentators on RDA and the present paper is of course that previous authors find the above argument compelling and try to fix it by adding something—'Humean' or not—to the original Humean basis, whereas the present paper doesn't find RDA compelling.

⁴ Both Katherine Hawley and an anonymous referee suggested something like the first 'argument by degree' intuition pump; Mark Crimmins, without advocating RDA, mentioned the second. I'm grateful to all three.

In order to get a flavour of the kinds of responses in the literature, let me briefly mention a few.

- (a) The argument shows that we require a causal theory of identity, where the causation is understood as non-Humean causation (Armstrong 1980). The two discs differ in the non-Humean causal relations among parts of the stages of the two discs. ‘Perhaps only causal singularists have access to the kind of glue that is strong enough to make the temporal parts of homogeneous stuff stick together’ (Zimmerman, p. 285).
- (b) The Humean basis must be ‘beefed up’ with instantaneous velocities. However, to work, instantaneous velocities must not be understood in a Russellian manner (see below). The intrinsic instantaneous velocities needed, such as those described by Michael Tooley, are non-Humean, so again HS fails (Zimmerman 1998).
- (c) ‘Second-order quasi-qualities having the character of vectors’ are needed (Robinson 1989, p. 406). This is also the fix recently advocated by Lewis.
- (d) We should posit ‘non-supervenient, non-spatiotemporal external relations,’ analogous to the non-supervenient relations allegedly found in quantum mechanics (Hawley 1999). On this view, a kind of *temporal* non-locality is needed in order to distinguish rotating from stationary homogeneous discs.
- (e) Tropes, which persist without temporal parts, can distinguish the rotation from non-rotation (Ehring 1997).

Each of these authors agrees that to handle rotating homogeneous discs we require something absent from the original basis. They disagree only when reaching into their bags of extra entities.

Before examining RDA further, let me first put aside the objection that perhaps initially springs to mind, namely, that the two discs differ in their instantaneous angular velocities. The reason for neglecting this response is not that it is necessarily wrong. Rather, the reason is that it is controversial, yet if I am right RDA fails so we need not engage the dispute over velocities. The question arises over the interpretation of instantaneous velocities. Are there really ‘states of motion’ defined at temporal instants, and if so, are they Humean or non-Humean? Or is there ‘no such thing as velocity except in the sense of a real number which is the limit of a certain set of quotients’ (Russell, 1937, p. 473).

These are interesting questions I will leave for the reader (see Tooley 1988 and Zimmerman 1998 for discussion).

2. Externalism, hands, and the no-difference reply

Analysing RDA is frustrating because the possible worlds described are left so vague. Proponents of RDA never specify physical properties of the possible worlds that might be relevant, e.g., its spacetime structure and the physics of homogeneous matter. Nor do they relate RDA to the apparently similar centuries' old problem of explaining rigid body circular rotation. As we will see, this is not too surprising, for failing to specify the physical laws governing rotating disc worlds is a crucial part of the argument itself. Fortunately, the physics of these worlds will not much matter for the counter-argument; where I assume any particular physics I will mention so explicitly.

To begin, note that the two possible worlds must be, apart from the (non-)rotation of the discs, 'in all other respects just alike in their distribution of qualities'. Otherwise RDA poses HS no threat. For if we allowed the two discs to occupy worlds with different distributions of qualities, then the Humean would be able to find the rotation through the characteristic events associated with rotating discs.⁵ If the disc is a homogeneous table with plates on it, the rotation (and type of rotation, e.g., non-accelerating, counter-clockwise) will quickly become apparent.

That the discs' environments must be effectively the same raises the question I want to press: *how is rotation understood in this argument?* For example, if the environments are the same, then it appears that we should conceive the rotation as an intrinsic property of the disc (or internal relations between spatial parts of the disc). And indeed, this is the way commentators on the argument appear to understand the rotation.⁶

Before pursuing this question directly (see the next section), it is worth taking a detour through some famous thought experiments that are strikingly similar to the current one. Consideration of these examples will suggest the right line to take on RDA.

⁵ Another possibility is that the two worlds differ in their distribution of qualities, but that this difference is not relevant to the discs' rotation or non-rotation (for either Humeans or non-Humeans). To save repeating this caveat throughout the paper, let's agree to count this possibility as a case where, for all intents and purposes, the distributions are effectively the same.

⁶ Hawley 1999 claims the rotation is intrinsic, but allows (p. 54, fn. 3) that the disc's rotation can be conceived relationally between its spatial parts and other physical objects or spacetime points. She says this still won't help the Humean. However, unless she gives the Humean the trans-temporal identity of spatial parts needed, I'm not convinced a relational understanding of rot-

Notice that since the environment is effectively the same in both possible worlds, it doesn't do a lot in the argument. For the purpose of an analogy, I propose that we temporarily ignore the discs' environments. The question, in this case, is whether Humeanism can distinguish a rotating from a stationary disc in an otherwise empty universe. Phrased like this, the argument ought to sound familiar. The argument is, superficially at least, isomorphic to thought experiments arising in the classic debate over whether we should conceive space and time absolutely or relationally. Newton famously argued for absolute space by claiming relationalists such as Leibniz could not distinguish two spheres attached by a cord rotating in an otherwise empty universe from two spheres in such a universe not rotating. Leibniz, believing he could do away with relations, even spatiotemporal relations, can be seen as holding a kind of extreme supervenience doctrine.

Comparing Newton's argument to RDA, however, is grossly unfair to Newton. Newton's argument, unlike RDA, isn't merely a conceivability argument. Newton didn't merely stipulate that we can conceive of the two globes rotating or not as an argument against Leibniz. That would have begged the question against Leibniz. Rather, Newton of course had an empirically adequate, simple and powerful mechanics supplemented with his gravitational theory. His mechanics and gravitational theory together *imply* that one can experimentally distinguish two rotating globes from two stationary globes.⁷ Newton's claim that the two worlds are different, therefore, was supplemented by perhaps the most successful theory ever discovered, not merely by common-sense intuitions.

However, Kant's famous argument that chirality or handedness implies the existence of absolute space *is* a conceivability argument of a sort. True, we do know empirically that there really are right hands and left hands. But the crux of the argument turns on a point about conce-

ation can get off the ground when the relata are all the same (because the environments are the same). Perhaps she means that the rotation is to be cashed out via some primitive non-Humean relations one disc has to the environment that the other does not? In any case, the motion cannot be understood the traditional way a relationalist understands the motion; that is, via 'externalism' (discussed below).

ivability. We can readily imagine, says Kant, a single hand in anotherwise empty universe. Is it right- or left-handed? It must be one or the other. Kant concluded that only relations between parts of the hand and absolute space could distinguish one hand from the other. His argument derives its force not from physics, but from the apparent

⁷ For further discussion and references on this point and related ones to follow, see Earman 1989.

obviousness of a hand needing to be either right-handed or left-handed.

This argument is similar to RDA. Both claim that their opponents, using only the resources available to them (relations for the relationalist, the Humean basis for Humeans), cannot distinguish two quite distinct possible worlds (rotating versus non-rotating worlds, single left-hand versus single right-hand worlds). Doing so requires more than the opponent allows (relations between objects and space, non-Humean properties). Indeed, we can make the arguments slightly more similar. Assuming Newtonian spacetime with its absolute standard of rest is not crucial to the argument, a harmless change of co-ordinates will transform our case into one with one disc rotating clockwise and the other rotating counter-clockwise. The familiar ‘right-hand rule’ from elementary physics will then leave our thumb pointing down in one case and up in the other (though this of course doesn’t make the discs enantiomorphs), leaving *a sense* in which one disc is right-handed and the other left-handed.

I mention this analogy to our present argument because the relationalist counter-arguments to Kant (and Newton) suggest an initial line of attack on our present argument. I do not mean to tie the two debates together, with relationalists going one way and absolutists another on HS. Nor do I believe the relationalist responses to Kant (and especially Newton) are necessarily correct. They merely suggest the correct response to RDA.

Relationalists and even some absolutists reply to Kant that there is *no difference* between the two possible worlds described. Call ‘externalism’ the doctrine that maintains that a hand’s being left or right depends on how it is related to other asymmetrical, that is, enantiomorphic) objects. According to externalism, since Kant’s two worlds share all the same relations they are at best two descriptions of the same possible world. For handedness to make sense externally there would need to be another asymmetric object to refer to. Since there isn’t, there simply is no fact of the matter about the single hand’s rightness or leftness, common sense protests notwithstanding. (In defence, externalists point out that handedness appears to depend on the global topology, not intrinsic features of the object. In non-orientable three-spaces, one *can* transform a right-hand into a left-hand merely by travelling.)

Advocates of HS should respond similarly, claiming that there is no difference between the two possible worlds of the RDA. They are at best two descriptions of the same possible world.

To this response absolutists pose of number of counterfactuals

designed to make relationalists squirm. Kant points out that we must conceive of a hand as being either right- or left-handed. Surely, if I were to introduce the glove on my right-hand into the one-hand world, it is not indeterminate whether it would fit?

Not surprisingly, some commentators on RDA entertain counterfactuals similar to the Kantian one above (Hawley 1999; Shoemaker 1984). But of all the proponents of RDA, only Hawley explicitly considers the ‘no-difference’ defence of HS. Against those who would respond to RDA in this way, she writes

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 (Hawley 1999 p. 55).

She compares this kind of indeterminacy to the indeterminacy found in evaluating counterfactual measurements in stochastic scenarios. (E.g., in the actual world I measure the spin of a neutron while standing and record ‘spin up.’ If I had been sitting, the spin of the neutron would have been ____?) She complains that neither the disc’s rotation nor its measurement need be indeterministic, which leaves it mysterious why the counterfactuals should behave as she supposes. She goes on to worry about how advocates of the no-difference response would handle backtracking counterfactuals such as ‘if the disc had been made inhomogeneous (say, through a measurement), then it would have had a determinate angular velocity, even before the measurement.’ She writes, ‘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’ (Hawley 1999 p. 56). To suppose otherwise, that the dust particle creates ‘new’ determinacy, would, she claims, ‘produce a bizarre classical analogue of the quantum measurement problem’ (Hawley 1999 p. 56). The supporter of the no-difference reply, she thinks, wants to have it both ways. They want to give determinate answers to these counterfactuals while at the same time maintaining that there is no determinate fact of the matter in the isolated (pre-measurement) case.

Externalists reply to Kant that introducing an outsider into the otherwise empty world changes everything. In Kant’s thought experiment, more details need to be specified about the addition of the glove to the world before we can assess counterfactuals such as ‘if the glove on my right hand existed in the one-hand world, the glove would fit the hand’. For the externalist, the labels ‘left’ and ‘right’ are arbitrary. The only fact of the matter is whether two hands are the same or different in

orientation. There are correspondingly two ways to introduce a hand and a glove into the world: either they are of the same orientation or not. This information must be included in any complete specification of the possible world picked out by the antecedent. The relationalist's answer is then trivial but determinate. If the glove has the same orientation as the hand, then the glove would fit; otherwise, it wouldn't fit. In this way the solitary hand's handedness may be indeterminate, but counterfactuals about what would happen to this hand in non-solitary scenarios may be determinate.

To the externalist, asking whether a single hand in an otherwise empty world is right or left is like asking whether an arrow in an otherwise empty world is pointing up or down. The opponent assumes a difference where there is none. Differences exist only when other asymmetrical objects enter the world.

This is precisely how the defender of HS should respond to Hawley. Once the counterfactuals make sense 'externally' there is no problem in providing determinate truth-values. And *until* the counterfactuals make sense externally they don't warrant determinate values. What is it to make sense externally? For handedness to make sense externally there need to be hands of opposite orientation around. For up and down to make sense externally different directions need to be defined with respect to a fixed reference point, e.g., the gravitational gradient on the earth. Similarly, for rotation to make sense externally we need present the physical effects characteristic of rotation, e.g., the surface tension on discs typical of rotation, angular momentum about their centre of mass, the distortion typical of rotation, the trajectories typical of spinning objects, etc. (After developing the argument of the next section I'll say a word about what particular physical effects, if any, are needed.) Thus, if someone splashed paint on the disc, then the disc is (non-)rotating if the paint blotches (do not) spin around with respect to some second party's frame of reference. If I touch the disc and there is(not) some effect characteristic of rotation, then the disc is (non-) rotating. On an externalist reading, these counterfactuals pose no difficulty for HS.

What about backtracking counterfactuals? These are trickier, and I can imagine different externalist responses to Hawley on this point. But it is enough for us to see one natural way of dealing with these. Consider, for instance, a 'Best System' externalist; that is, an externalist making use of Lewis's (Lewis 1986, 1994) 'package deal' on laws, chances, etc. Consider a Best System analysis of the rotating disc worlds. We look at the Humean array of qualities, *past, present and*

future, and submit the generalisations characterising this world to a competition to see which ones maximise strength and simplicity. Clearly, since the two worlds are point-by-point identical outside the boundaries of the discs, they will share the same Best System. They will then have the same laws, the same causes and effects, etc. Notice that on this picture, facts about the rotation of a homogeneous object are like all other causal facts (in Humean worlds): namely, they are made true ‘non-locally,’ by the full array of qualities. The landing of the speck of dust on the disc doesn’t *cause* the disc to rotate, but it may be the reason why the Best System *counts* the disc as rotating. In general, Humeans make use of global considerations when ascribing properties—there is nothing particularly new or unusual here. Hawley’s problem with back-trackers is simply a worry about Humeanism, a worry that by itself cannot be turned into an objection without begging the question.

It may be tempting to conclude from this discussion that RDA is only as weak as externalism is strong, and one might point out that Kant’s argument is hardly a non-starter. In the next section we shall see that externalism is not needed to combat successfully RDA. But even at this stage of the argument, we can see that there is something right about the no-difference reply. Because there is no absolute top and bottom to the discs, the present case is more like the case of the lonely arrow world than the lonely hand world. We need only turn the clockwise rotating disc over to bring the two discs into the same direction of rotation. In contrast to the non-orientable three-space needed to make hands congruent, we need do almost nothing to make the two discs congruent. The present argument is a kind of parody of Kant’s: it is not substantially different from an argument claiming that there is a fact of the matter about whether an arrow in an otherwise empty world is pointing up or down.

3. Ghostly rotation.

The analogy with Kant’s argument is useful motivation for the ‘no-difference’ reply, but we can see that this is the correct reply independently of externalist analyses of rotation. We don’t need anything as strong as the metaphysical doctrines of relationalism or externalism to make the weaker methodological objection that there is insufficient reason to posit a difference between the two worlds.

Above I removed the environment from the scenario, but I did this only for the sake of expediency. Removing the environment made the analogy with Kant’s case more noticeable. But of course, the advocate of RDA needs the environment. A world consisting of a lonely disc in an empty space is hardly a ‘world like ours’.

We saw that the environment of each world must be effectively the same. Otherwise, if the world contains the phenomena characteristic of rotation in our world, then it is easy for the Humean to distinguish the two cases. Armstrong, for instance, affirms that ‘there is no way of telling’ whether the disc is rotating or not (Armstrong 1980, p. 77). But isn’t this odd? The rotation with which we’re familiar always has physical effects, e.g., inertial effects, even if imperceptably minute. How do proponents of RDA conceive of the disc’s rotation? If we take a plate and place it on a putatively rotating homogeneous disc, what happens?

Proponents of RDA seem to be divided. Above we saw that Hawley implicitly suggested that a splash of paint or a piece of dust would enable one to tell whether the disc was rotating or not. Rotating homogeneous discs would display rotational phenomena, if only given the chance, on this view. So a plate placed on the disc should spin around the axis of symmetry if the disc is rotating. On this view, the physical laws of rotating disc worlds may be similar to ours, but for the argument to work the discs would have to be extremely isolated, so that no dust, no photon...nothing touches the disc, for otherwise rotational phenomena would be displayed.

What about other rotational phenomena, such as the fact that (recalling Newton’s bucket) in worlds like ours a homogeneous rotating cup of coffee should have a concave surface in contrast to the flat surface of the stationary cup. To this means of distinguishing the two discs, Hawley writes:

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. (Hawley 1999, p. 61)

Zimmerman (1998, pp. 268–9) takes this kind of stance throughout, maintaining that there is no difference in physical effects between a homogeneous disc rotating clockwise and its twin rotating counter-clockwise (since their centrifugal forces are the same).⁸ The symmetry between the two disc worlds implies that all other *possible* effects will be the same, too. A plate placed on a rotating homogeneous disc presumably will stay still, since the disc is perfectly smooth and therefore fric-

⁸ Zimmerman believes this clockwise and counter-clockwise example is different than the original. But unless Newtonian spacetime’s absolute standard of rest is essential to the argument, this is just the original example from a different frame of reference.

tionless. On this view, rotating discs do not display rotational phenomena, even if given the chance.

In either world I find it mysterious why one would ever posit rotation in one disc and non-rotation in another. The externalist's objection of §2 claimed that certain physical effects characteristic of rotation are essential to rotation being rotation. That can be false and still it be true that the physical effects characteristic of rotation are essential to us having a reason to believe an object is rotating.

Defenders of RDA seem forced into saying that there is no possible way of distinguishing the rotating from the non-rotating disc. If a single photon or piece of dust would reveal the rotation, then the example only works in extreme cases, ones wherein the worlds involved are uncontroversially very far from our world. A world wherein a disc is so isolated that not a single photon or other particle interacts with it is not a world like ours. Nor is such a world compatible with the laws of physics as we know them, for (contra Zimmerman—see below) a universal force like gravity will detect the difference between rotation and non-rotation. What is needed is a world with a disc that is not coupled to any of the fields that exist in our world. But then such a disc is no different from a ghost, and is not something Humeans or non-Humeans ought to posit.

If proponents of RDA maintain that there is no way of telling whether one of the discs is rotating, then again we want to know why we should posit rotation, or better, a difference between the two worlds. If the physical laws of this world are anything like ours, we would expect plenty of distinguishing physical effects. For instance, a rotating disc should stretch perpendicular to its axis of rotation; the surface of homogeneous coffee should go concave when rotating (we'll return to Hawley's point below); and rotating homogeneous spheres should be ellipsoid shaped. In our world, relative motion between parts of a body is not necessary to expect all the inertial effects common to rotation (a fact which, incidentally, plagues relational accounts of rotation). So being homogeneous should not make these effects disappear—so long as the discs have mass. Maybe with compensating forces these objects could remain rigid, for rigid bodies are theoretically possible according to classical physics. But still these compensating forces would need to be around, thereby ruining the example, and also in our world strictly rigid bodies are impossible (they require 'shape-restoring' forces that travel faster than light, and are therefore ruled out by relativity). The more that you think about the discs, the more perplexing they become ... If the laws are anything like ours, homogeneous matter sculpted into

a top should display its rotation by precessing. Do homogeneous discs rotating at different speeds have different kinetic energies, or different thermal properties? And in general relativity, the gravitational field can tell the difference between a single elementary individual rotating and one non-rotating (contrary to Zimmerman's claim about gravity), for the spin couples to the curvature of spacetime producing deviations from geodesic motion. Rotating objects will 'drag' their inertial frames around with them—much as objects rotating in water will drag water around them—and this will be manifest in the properties of the spacetime (see Misner, Thorne and Wheeler 1973, pp. 1117–1121).

It should be clear that the rotating disc worlds—as necessarily understood by RDA—are very far from worlds like ours. They are therefore no threat to HS. However, I think the more fundamental problem with RDA is that there is simply no reason to posit rotation in one of the worlds and non-rotation in the other. Proponents of RDA are asking us to believe that a disc, displaying none of the above phenomena, is rotating. But why should we? Those operating with any of the maxims found in scientific methodology would never posit rotation in one world and non-rotation in another. There must be some reason—some speck of dust, some single photon, or some gravitational field value behaving differently—to posit rotation in one world and non-rotation in the other. Otherwise one is positing a distinction without a difference, a cardinal sin according to any scientific methodology. Why in the world posit a property in one of these worlds and not the other if the worlds are indistinguishable? What science would condone such a posit?⁹

Even when intrinsic 'rotation' is posited, as some interpret spin in quantum mechanics, one posits it only because otherwise alike experimental situations give different experimental outcomes. Mill's methods or similar methodological advice then warrant ascribing different properties to the situations. RDA's rotation, by contrast, does not ever distinguish itself. It is hardly distinct from the souls, ghosts and fairies that might also live in discs. Indeed, the argument appears little different than positing a soul in one of the discs and then complaining that HS can't capture the difference between discs with souls and discs without. One operating with Occam's razor or ordinary scientific

⁹ Note that this argument is not verificationist in any way. It should not be confused with the complaint that the rotational effects are unobservable. Rather, the claim is that there aren't any observable or *unobservable* effects in the world that would be good evidence for positing rotation in one world and non-rotation in the other.

methodology would quickly and rightly excise these impotent phantasms from the discs.

There are also ontologically based objections to RDA, though I do not wish to defend any of them here. These objections state that rotational phenomena are essential to rotation *being* rotation. Absent certain effects, a process just doesn't count as rotation. The externalist reply of §2 was an objection along these lines. On this theory, we discover that rotation is essentially bound up with the motions of other bodies, akin to the discovery that up and down are essentially bound up with the direction of the local gravitational gradient. In metaphysics one can find other principles that might share this line. One operating with the some variant of the metaphysical principle that one individuates properties by their causal role (Shoemaker 1998) might do the same (though perhaps not Shoemaker—see Shoemaker 1984). Since the two discs appear to occupy the same causal role in the two worlds, they do not have different properties. They are either both rotating or both stationary. The worlds conceived in RDA may be compared to the imagining of water that is not H₂O according to Kripkean semantics. And one operating with the Best System package deal should say something similar. Since the two worlds would share the same Best System, and positing a distinction that makes no difference is methodologically abhorrent, the Best System advocate should say that either both discs are rotating or neither is. Either way an advocate of the package deal should think there is no difference between the two worlds. Lewis (Lewis 1999) wants to give the Humean the resources necessary to believe in the possibilities described by RDA, but it seems to me that these possibilities are precisely the sorts that Humeans ought to deny as genuine.

Distinguishing the methodological from the ontological objections to RDA helps one to answer Hawley's point that concave surfaces need not be essential to rotation. The metaphysical objections may claim that concave surfaces are essential to rotation *being* rotation, and these objections are good to the extent that their analysis of properties, etc., is convincing. But we don't need to defend a thesis so strong to challenge RDA. So let me grant that we should not expect all the physical effects characteristic of rotation to always be present. Indeed, a recent paper by David Malament (Malament 1999) discusses some natural features of rotation in general relativity, but finds that they are not always co-extensive in all the models of general relativity. Given Malament's proof, we know that some of the physical associations with rotation in our world don't even hold in *nomologically* possible worlds. Our con-

cept of rotation is perhaps rich enough to not be analytically tied to any *one* particular physical effect.

But still, there must be *some* physical effect present in order for us to have reason to count an object as rotating. It may not be any particular one, but there has to be *something* to give one reason to say the coffee cup is rotating (some effect, say, from a list of the associations typical in worlds like ours). Otherwise, as above, it is little different than positing a soul in one of the discs. When one says it's possible for there to be a rotating coffee cup with a flat surface, a natural reaction is to wonder what makes it the case that the cup is rotating rather than stationary. If the answer appeals to its (say) inward spring force or its particular reflection of light, we might be persuaded that the coffee is rotating even if its surface is flat. But using these effects, the Humean can distinguish rotation from non-rotation as well as the non-Humean. And the Humean only needs *one* such physical effect to distinguish rotation from non-rotation. Unless the proponent of this argument is positing 'ghostly' rotation, the Humean has no problem. But ghostly rotation is precisely what is being posited, for we're being asked not to believe that a rotating coffee cup with a flat surface is rotating, but that a coffee cup is rotating even though it is displaying all and only the properties science tells us are characteristic of non-rotation! Hawley's point may challenge one holding the ontological version of the objection, but it doesn't affect the methodological version.

Proponents of RDA face a dilemma: if the argument is not to be a howler, the discs' environments must be effectively the same; but if the environments are effectively the same, the rotation must be outside the world's network of causes and effects. The rotation must be a difference that makes no difference. Not only would science and Occam's razor reject such a difference, but so would various plausible metaphysical principles.

4. Conclusion.

Finally, let us return to our initial intuition pumps and see what can be said. I myself find the above arguments sufficiently compelling that I would be prepared to accept some counter-intuitive consequences, if any; however, it would of course be preferable to explain these intuitions away. Fortunately I think we can do this.

The world wherein polka dots fall off the disc is easy enough to handle. The Humean can say that the bare homogeneous disc is rotating by simply appealing to the global facts of this world, in the manner described above. Since the disc was rotating in a perfectly Humean way,

surely (say) a Best System theorist would claim it continues to rotate. Looked at globally—which is the way Humeans should look at matters—there is no problem. (Alternatively, the Humean might ask for the world to be described in greater detail, to see whether there really is more evidence that the disc is rotating than that the dots are rotating around a still disc. If the latter turned out the superior explanation given the best science of the world—that is, given other behaviour of polka dots, homogeneous matter, etc. in this world—then the Humean may say the bare disc does not rotate without the absurdity of it stopping instantaneously.)

The second, slightly more awkward case of the two machines can also be handled. This world is insufficiently detailed for us to trust our initial intuitions. Here we need to think about the make-up of the machines. Even leaving aside the wildly unrealistic isolation and/or physics required by the two discs, we can still see problems. How does machine *A* manage to impart a motion to the homogeneous disc? For the example to work, the disc must be perfectly round about the axis of rotation: so there are no notches, bumps, etc., to which the machine can grab on in order to spin it. The disc must also be perfectly smooth, and therefore frictionless, so one can't just slap the disc in one direction and hope to impart a motion. A little further reflection reveals that it's quite magical how machine *A* imparts a spin to the disc. But absent some reason to think machine *A* imparted a motion, all we really have is a Humean regularity about the motion of objects placed on discs produced by *A*. In such an odd world, further causes of this motion are either mysterious or absent. In either case, the Humean can agree with the mountain of inductive evidence—claim objects on discs from *A* will rotate and those on *B* will not—without (because there is not sufficient evidence for it) claiming that discs from *A* spin and discs from *B* are still.

Nearly every article on the rotating disc and HS includes a section containing anxious hand wringing about the value of considering homogeneous matter worlds. What demarcates the 'inner sphere' of possibility from the 'outer sphere' that is irrelevant to a defence of HS? Where is perfectly homogeneous matter located? If my argument is right, rotating homogeneous discs prompt none of this worrying. And this is a good thing, too, for this particular kind of intuition-mongering very rarely bears fruit. The proponents of this argument have simply jumped the gun. With very little discussion of the details of the case, they have too quickly assumed the argument is sound and wanting of some (usually) non-Humean fix. So secure of its correctness are propo-

nents of RDA, some even pursue the effects of this non-Humean fix on other philosophical issues. However, all of this is much too premature. When clarified, the original argument is a kind of parody of Kant's argument about hands. But unlike Kant's argument, which involves many deep issues, this argument isn't very convincing. The property Humeans cannot recover is simply not worth recovering. Defenders of HS may need to increase the number of fundamental entities they're committed to for other reasons, but they shouldn't do so under pressure from RDA.

To my mind, the foregoing also illustrates a more general lesson for metaphysics. Intuitions about conceivable states of affairs should only be taken seriously when the worlds they are picking out are sufficiently detailed. The merit of discussing truly bizarre worlds is highly controversial. But what shouldn't be so contentious is the claim that one can only hope to get some mileage out of these conceivings when we fill in the details. That RDA—and many arguments similar to it—gets anywhere is due solely to the worlds it conceives being woefully under-described.¹⁰

*Department of Philosophy, Logic and
Scientific Method
The London School of Economics
Houghton St
London WC2A 2AE
UK*

CRAIG CALLENDER

*Department of Philosophy
The University of California
San Diego
La Jolla
CA92093-0119
USA
ccallender@ucsd.edu*

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