Symmetry Reasoning as the Elimination of Arbitrariness

Symmetries in physics are often treated as a guide to reality. The aim of this paper is to propose an account of this symmetry-to-reality reasoning. According to the account proposed, a symmetry shows us that a given distribution of variant properties is not modally fixed by the distribution of the invariant properties relative to a given set of laws. If, furthermore, our objective evidence does not imply any one particular distribution of variant properties, we face an arbitrary choice. Denying the reality of variant properties eliminates the arbitrary choice that we would otherwise be faced with – and this how we reason to the unreality of the variant properties. The proposed arbitrariness account will be compared with two rival accounts: the account on which a symmetry is taken to imply physical redundancy, and the account on which a symmetry is taken to imply unobservability. The redundancy account appears to prejudge the unreality of the variant properties. The unobservability accounts requires controversial assumptions about what we can observe. The proposed arbitrariness account is shown to be free of these shortcomings.

1. Introduction

There is a common line of reasoning in physics, from given types of symmetries of a given set of laws to the unreality of certain properties that vary in those symmetries. The symmetry-to-reality reasoning forms a bridge principle between physics and metaphysics, and plays a major role in determining the current views on the structure of spacetime and objects. The symmetry-to-reality reasoning plays a central role in the way in which the scientific image drifts away from a more naïve view of the world, and it plays a central role in our overall scientific understanding of the world. The symmetry reasoning also affects theory integration. For example, the Minkowskian conception of spacetime eliminates absolute simultaneity on the basis of its variance in symmetries of the special theory of relativity and it is because of this elimination of absolute simultaneity that there are difficulties in meshing the special theory of relativity with various interpretations of quantum mechanics (see Maudlin 2011: Ch. 9). It is thus important that we understand what sort of steps are involved in the symmetry-to-reality reasoning. The aim of this paper is to propose an account of what is involved in this symmetry-to-reality reasoning.

The aim is not show *that* the symmetry-to-reality reasoning is justified. The aim is to sketch an account of what the symmetry reasoning plausibly consists in – what the relevant steps are. Whether those steps are indeed justified is an epistemological question that lies beyond the scope of this paper. This is not say that the epistemological question is not relevant to the evaluation of the offered account: if the proposed account is one on which the reasoning turns out to be unjustified, charitability considerations might motivate us to look for a better one. The aim of the current paper is therefore modest: to formulate a proposal and show why it deserves further attention, in particular because it seems to avoid certain problems besetting rival accounts.

Two rival accounts are discussed and criticized. The first holds that a symmetry is taken to imply physical redundancy, or superfluous theoretical structure. I argue that this account needs to prejudge the unreality of the variant properties. The second rival account holds that a symmetry is taken to imply the unobservability of that property. I will formulate an objection to a recent argument that aims to establish that the unobservability of a property can be inferred from its variance. Given that the argument fails, the unobservability accounts requires controversial assumptions about what we can observe. The proposed arbitrariness account is shown to be free of these shortcomings.

The paper will proceed as follows. The paper starts with a preliminary discussion of some of the relevant notions (in §2). Next (in §3), the proposed arbitrariness account is put forward. Then (in §4), I will discuss a problem for the view that symmetry implies theoretical redundancy and show how the problem does not arise for the arbitrariness account. Next (in §5), I will argue against the idea that symmetry implies unobservability and show how the arbitrariness account does not require any controversial commitments about what we do or do not observe.

2. *Preliminaries*

It is not obvious how best to approach the topic of symmetry reasoning. The issue is tricky first of all because the notion of the variance of a property in a set of laws and the notion of the symmetries of the relevant laws form a tightly interrelated conceptual web. We could say that a property F is variant in some set of laws if and only if there are symmetries of those laws in which property F varies. Or we can say that symmetries are those transformations of a system governed by some set of laws that only change variant properties in certain ways, leaving all the invariant properties unaffected. On this approach the challenge is to somehow break (or at least widen) this tight web of concepts by offering an independent way of specifying what symmetries are. The question of what justifies the symmetry-to-reality reasoning might well constrain our very definition of symmetries on this approach: the symmetries are to be those changes to a system variance across which can justifiedly be treated as a mark of unreality (Dasgupta 2016: 842). In that sense, defining symmetries prior to answering what justifies the symmetry-to-reality question risks prejudging the question of justification.

The topic admits of an alternative approach, however. One can also construe a symmetry as a purely formal notion, namely as those type of transformations that preserve both the satisfaction and non-satisfaction of the natural laws in question (Ismael and van Fraassen 2003: 378). Variance in symmetries thus conceived does not in general underwrite elimination of the variant properties (Ismael and van Fraassen 2003: 378-9; cf. Belot 2013: §3). Think for example of a transformation from a system with certain initial conditions to one with different initial conditions, or from a system with one particular to one with only one. Such transformations can preserve the satisfaction and non-satisfaction of the laws, but we do not want to conclude that all initial conditions or cardinalities of a system are unreal. Put in these terms, the challenge is to specify the *relevant kind* of symmetries that do motivate the unreality of whatever is variant in them. On this approach, the challenge is to find the further conditions that are met by those symmetries that are involved in the paradigm cases of symmetry-to-reality reasoning. This will be the approach that I will adopt here.

It will help to focus on a single paradigm case of symmetry-to-reality reasoning. Our discussion will focus on dynamical laws, i.e. laws governing the motion of physical systems in terms of forces, distances and masses. In particular, I will follow Belot (2013) and Dasgupta (2016) in restricting most of the discussion to a simple toy case involving Newtonian physics. As our toy case, we will consider a system governed by the laws of Newtonian Gravitation (NG): the second law of motion ($F = ma$) and the inverse-square gravitational force law ($F = Gm_1m_2/r^2$). The inputs of the laws are therefore masses (m, m_1, m_2, …), acceleration (a), the gravitational constant (G), the spatial distance between the relevant centres of mass (r) and force (F). As mentioned above, a symmetry of these laws is any mapping that takes a system that satisfies the laws to one that does too and that takes any system that does not satisfy the laws to one that doesn't either. We can focus on a paradigm example such as adding a uniform velocity boost of 5 mph towards the north. Since such a uniform velocity boost is a symmetry of the laws of NG, and since absolute velocity is variant in this symmetry (varying between the original and the boosted scenario, even though the masses, accelerations, distances and so on remain the same), this leads to the view that absolute velocities are unreal. This is a paradigm case of symmetry-to-reality reasoning, which motivates the rejection of a Newtonian conception of space and time in favour of a Galilean (or Neo-Newtonian) conception of spacetime in which things do not instantiate absolute velocities (rates of space traversed by a single thing in an interval of time) but only relative velocities (rates of changes of distances between multiple things in an interval of time) since these *are* invariant properties of the laws of NG. It can also be helpful to speak of the symmetry *of* a given system *given* certain laws. If we have a physical system whose distribution of these quantities is governed by the laws of Newtonian Gravitation (NG), a symmetry of that system is any transformation of that system whose distribution of these quantities continues to satisfy the laws of Newtonian Gravitation (NG).

The literature has proposed various distinctions amongst different types of symmetries. We can distinguish between symmetries that transform temporal or spatial variables and those that transform other variables (the external and internal symmetries, respectively), between symmetries that transform everything in space and time in the same way and those that transform different regions of space and time in different ways (the global and local symmetries, respectively), and between symmetries that merely flip or inverse matters and symmetries that transform things in a continuous manner (the discrete and continuous symmetries, respectively). Most of the discussion will focus on a global, external, and continuous symmetry, namely the mentioned uniform velocity boost. For discussion of these differences, see Kosso (2000: 84-85) and Brading and Castellani (2007).

We can also distinguish between thinking of the transformations as acting on the coordinates used to describe a system – i.e. as passive – and thinking of the transformations as acting on the physical system itself – i.e. as active (Brading and Castellani 2007: 1342–3). I will speak of the transformations as acting on the physical system itself (so as active). Thinking of the transformations as passive is a tempting way of thinking of symmetries, yet quite misleading, at least in the current context. If we consider transformations on the coordinate systems we use to represent a physical system, then the symmetries are those transformations that leave the intrinsic structure of the represented system unaffected; that is to say, the symmetries are then those coordinate transformations that relate different ways of representing the system that are all equally good because they agree on what is out there. So, what are equally good coordinate descriptions depends precisely on what is out there (cf. North 2009: 62), but that is what the symmetry-to-reality reasoning is meant to help figure out. If absolute velocity were real and instantiated out there for example, then coordinate descriptions that imply different absolute velocities cannot be equally good. Our task is to figure out what initially makes us think of the symmetry transformations as transformation of mere modes of description, and for this purpose, we must start with a conception of the symmetries that does not prejudge this. We start therefore with thinking of the transformations as acting on the physical systems themselves.

3. The arbitrariness account

Our preliminary choice of approach gives us a relatively focussed questions: what are the further conditions that are met by those symmetries that are involved in a paradigm case of symmetry-to-reality reasoning, such as the case involving the laws of NG and the symmetry that results from adding a uniform velocity boost of 5 mph towards the north?

What does the variance of the distribution of a certain property in a symmetry of a system tell us about that property? It tells us something about the relation between that property and the invariant properties of the system: namely that the invariant properties plus the laws do not fix or determine the distribution of the variant property. For example, the absolute velocities vary across the velocity boost of a system governed by the laws of Newtonian Gravitation whilst the relative velocities remain invariant. This tells us that the relative velocities together with the laws of Newtonian Gravitation are compatible both with a distribution of the set of unboosted absolute velocities as well as with the set of boosted velocities. The given distribution of the absolute velocities float free from the distribution of the invariant properties: a change in their distribution does not necessarily imply a change in the invariant properties, as shown by the uniform velocity boost.

When a property varies in a symmetry, we know that after having assigned the invariant properties to a system we still face the choice over whether the system has these variant properties or those other ones. Sometimes a single distribution of variant properties will be privileged by our objective evidence. For example, a transformation of the initial conditions of a system might count as a symmetry of that system relative to a certain set of laws. But, given what we all observe the system to be like, it is clear that only one of the symmetry-related distributions of initial conditions squares with our observations of the system. A single set of initial conditions might thus be privileged by our objective evidence. But, sometimes, no single distribution of variant properties will be so privileged. The choice will then seem arbitrary. I want to propose that the further condition that is met by symmetries that are involved in a paradigm case of symmetry-to-reality reasoning is that of relating scenarios between which we can only make an arbitrary choice. By denying that the differences between the symmetry-related scenarios correspond to differences in the world, there is no longer any need to choose which scenario *truly* corresponds to the world. By denying that the variant properties make for real differences in the world, we undermine the arbitrary choice that we would otherwise be faced with.

The account of the symmetry-to-reality reasoning is suggested by comment about special relativity by Sklar (in turn citing von Neumann):

> As von Neumann has remarked, the problem with a non-relativistic explanation of the facts is not that one can't be given but that too many can be given, and no reason can be given for selecting one rather than another. In a clear sense, the motivation behind special relativity is the elimination of arbitrary choice from physics (Sklar 1977: 280).

One can offer multiple frame-dependent explanations of phenomena, phenomena which can themselves be described in frame-dependent terms (see Bell 1976/1987). We further lack any basis for privileging any one frame of reference. By denying that the differences between the frames are worldly differences, we avoid having to arbitrarily pick one frame of reference as the privileged one.

The guiding principle here is that, all things being equal, we prefer a theory that enforces no deep epistemic arbitrariness over a theory that does. For example, all things being equal, we prefer an interpretation of the special theory of relativity that does not force us to arbitrarily privilege one frame of reference over an interpretation that does. Such a privileging would give rise to the unanswerable question of why we assign these variant properties to things in particular. No objective experience or observation could help us answer this question.

The relevant kind of arbitrariness is familiar to us from everyday cases of perspectival matters. Imagine that we experience things in terms of such relations as *being on the left of* and *being on the right of* something. If we are facing each other, our experiences are of conflicting distributions of these properties: precisely everything that you observe as being on the left of other things I observe as being on the right of those things, and vice versa. Again, the distributions of these relations seem to be independent from those of all other properties: if I turn around, only these relations between things change, and nothing else. Because these properties are not in any lawlike manner entangled with other properties of things, it is physically impossible to experience any independent matter that will resolve our conflicting descriptions of the world. There is nothing that we can both experience from our oriented perspectives that will tell us that something is really on the left of something, or really on the right of it. These familiar cases of perspectival experiences are examples of the relevant kind of arbitrariness that emerges from the relevant cases of symmetry.

Let us look at the line of reasoning in more detail. Applied to our toy case, the proposed reasoning looks as follows. We consider a system governed by the laws of NG.

We find that there is a symmetry in the form of a uniform velocity boost. This confronts us with two epistemic possibilities: (1) that the world conforms to the original unboosted scenario, or (2) that it conforms to the boosted scenario (and, of course, there will be infinitely many other such scenarios). At this point, it can be hard to see whether we experience or otherwise detect absolute velocities in the world around us. There are two cases to consider: either we do not experience or measure any absolute velocities, or we do. If we do not experience or measure any absolute velocities, we also have no reason to pick any scenario over the other. Because, given the symmetry, our experience or measurements of other properties do not bear on our choice between (1) and (2). The choice is arbitrary. If we do experience or otherwise detect absolute velocities, we see that these experiences or measurements do not form a body of objective evidence. They rather form a body of perspectival experiences or measurements in the sense that equally good observers plausibly observe incompatible distributions of absolute velocities: some taking these things to be at rest, some taking these other things to be at rest. Where someone experiences things to be one way and another experiences it to be the boosted way, there is no independent reason why any of the experiences should be falsidical or veridical. In such a case, each of the two experiences is a rebutting defeater for the other, i.e. each experience prevents the other experience from justifying belief in the relevant distribution of absolute velocities (Pollock and Cruz 1999: 196). There is no empirical way of arbitrating the disagreement, not through further observation of other properties, not through our study of the past or future evolution of a system (given that the same disagreement will be found there as well), nor through further measurements of any kind, given that the variant properties are precisely variant in not being fixed by the other properties. So even if we experienced absolute velocities, these experiences would not constitute an *objective* body of evidence about the distribution of absolute velocities.

Admitting the reality of absolute velocities would therefore require that we arbitrarily privilege one distribution over others. Eliminating the absolute velocities removes the need to make this arbitrary choice.

This arbitrariness account strikes me as a prima facie plausible reconstruction of paradigm cases of symmetry-to-reality reasoning. As it turns out, the account also avoids certain problems besetting rival accounts.

4. The redundancy account of the symmetry-to-reality inference

One rival account of the symmetry-to-reality reasoning is based on the thought that variant properties are physically redundant properties, projecting superfluous structure onto the world. There are different ways of unpacking this thought. For example, one might think that the instantiation of absolute velocity makes no difference to the way a physical system evolves over time (Baker 2010: 1159), or that it is not required to underwrite the laws of motion governing the system (Earman 1989: 46). The central claim of the redundancy account is that variant properties play no real role in the dynamics of a physical systems, constituting theoretical danglers that are not required for any physical explanations. If absolute velocity is indeed epiphenomenal in this way, it falls to Ockham's razor as something we should dispense with. The symmetry-to-reality reasoning proceeds then from variance to the redundancy of the variant property, after which Ockham's razor provides the justification for the excision of the property from our metaphysics.

Why would anyone presume a connection between being a variant property and being physically redundant? Consider again the scenario of a physical system governed by the laws of Newtonian Gravitation (NG), and its uniform velocity boost. The idea behind the redundancy account is that only changes in the invariant properties at some time t_0 make a difference to what the laws of NG tell us about the system at a later time t_1. Because of this, changes in the variant properties at t_0 do not seem to make a difference to what the laws of NG tell us about the evolution of the system over time. In other words, the variant properties do not seem to make a difference to how the system is governed by NG, and because NG governs the evolution of a system over time, the variant properties do not seem to make a difference to the evolution of the system at all.

This redundancy account fails however, for a reason that is briefly pointed out by Sklar (1977: 180), and that has been worked out in more detail by Dasgupta (2016: §2.2). The problem with this account is that there is a missing step in the proposed reconstruction of the symmetry-to-reality reasoning. From the fact that certain properties make no difference to the invariant properties, we cannot infer that they make no difference at all. If there were variant properties, then their distribution would make a dynamic difference to the distribution of the variant properties at a later moment.

Consider an illustration. Say we have a system with only one particle. If we assume for the sake of argument that one of the particles is at rest at t_1 in our system, then it might turn out that it is at rest at t_1 because it was at rest at t_0 and no forces acted on it in the meantime. This means that the distribution of the absolute velocities at one time makes a difference to the distribution of absolute velocities at a later time. When our closed physical system is given a uniform velocity boost, we have a change in the absolute velocities that do not affect the properties that feature in the laws of NG alright, but they do make a difference to the evolution of the system over time *if* absolute velocities were real. In the original scenario, our particle is at rest at t_1 and this is explained in part by it being at rest at t_0, in the other case it is moving at 5mph towards the north at t_1 and this is explained in part by it moving at 5mph towards the north at t_0. In both the original and the boosted world, the absolute velocity at earlier times make a difference to the velocity at later times, and hence is not redundant (Dasgupta 2016: §2.2). The mere variance of a property in a symmetry does not imply its physical redundancy, and hence such redundancy cannot be involved in the eliminative reasoning concerning these properties

This failure of the redundancy account highlights a deeper issue. When Baker motivates the redundancy account, he points out that 'the language of fundamental physics is complete in a particular sense: in a satisfactory physical theory, the fundamental quantities are all dynamical difference-makers' (2010: 1158-9). Now note that, when we think of variant properties as making a difference to future distributions of those variant properties, the laws of NG fail to be complete in the sense of governing all quantities that are dynamic difference-makers, since the laws of NG are silent about the evolution of particular absolute velocities over time. For all that the laws of NG tell us, if there were absolute velocities, spontaneous uniform velocity boosts might be occurring from one time to the next. If there were absolute velocities, we would not think that such boosts occur and that there is a lawlike evolution of absolute velocities over time, and hence that the laws of NG fail to capture this lawlike evolution and fail to rule out spontaneous velocity boosts. The laws of NG would be incomplete.

Conversely, then, if we presume a set of laws to be complete before engaging in any symmetry-to-reality reasoning, we seem to be prejudging things. A set of laws is naturally considered to be the complete laws of motion when they capture everything about the dynamics of a physical system, i.e. everything there is to say about the way systems evolve over time. Assuming that some set of laws is complete is tantamount to assuming that properties that can vary across symmetries of those laws, and hence are not fixed by these laws, are not amongst the things involved in the dynamics of the system. This means that we are only justified in assuming the relevant laws to be complete if we already know that the variant properties are unreal.

The redundancy account must assume the relevant set of laws to be complete. If we start with a possibly incomplete collection of laws, then the variance of a property in those laws might just be due to their forming an incomplete set.

This then is the essential problem with the redundancy account: whether a set of laws is complete or not straightforwardly depends on what properties are instantiated out there, and yet it seems that we need to start with a complete set of laws in order to avoid eliminating too many properties on the redundancy account.

Dasgupta assumes that we have an independent handle on the completeness of the laws of nature and assumes that the following circle does not obtain: our belief in the completeness of the laws is motivated by a belief in the unreality of its variant properties while our belief in the unreality of those properties is motivated by a line of reasoning that needs to presume that the laws we start out with are complete (2016: 844). This is of course problematically circular. But it seems to me that the redundancy account cannot simply help itself to the assumption that the circularity does not obtain. On the contrary, I argued that the redundancy account cannot avoid the circularity: if it does not assume that the relevant set of laws are complete, we cannot conclude the physical redundancy of the variant properties but we are only justified in assuming the relevant laws to be complete if we already know that the variant properties are unreal.

The arbitrariness account avoids this problem because it does not need to assume that the relevant laws are complete. We have a given set of laws, and we do not yet know whether they are complete. We find out that certain properties turn out to be variant in symmetries of these laws. We then consider what distribution of variant properties we have good empirical reason to believe in. If we then find that we have no good objective reason to privilege one of the possible distributions of the variant properties, this gives us a defeasible reason to reject the unreality of the variant properties in order to avoid arbitrarily privileging one of the various incompatible distributions. If the variant properties are unreal, then the set of laws we started out with are thereby complete and do not fail to capture any lawlike evolution in the phenomena that would be constituted by those variant properties. There is therefore no need to presume that the laws are complete on the arbitrariness account, indeed, the symmetry-to-reality reasoning is plausibly taken to function as a symmetry-to-completeness reasoning as well, as it should.

5. The unobservability account of the symmetry-to-reality inference

Another popular account of the symmetry-to-reality inference is based on the thought that variant properties are unobservable (Ismael and van Fraassen 2003; and Dasgupta 2016). On this reconstruction of the symmetry-to-reality reasoning, its justification derives from the fact that invoking unobservable structure is a theoretical cost of a theory, and that any theory that is otherwise just as good but does not invoke the unobservable structure must be rationally preferred on the basis of Ockham's razor. Dasgupta (2016: §4.2; see also Roberts 2008: 159-62) supports the unobservability account with an argument purporting to show that the unobservability of a property follows from its variance in some set of laws. I think the argument fails, however. Because the argument fails, the account needs to rely on controversial assumptions about what can and cannot be observed.

First the setup of the argument. We turn again to our toy case and we make the further assumption that absolute velocity is observable only if there is some physically possible process that, when initiated to measure the absolute velocity of a given body at t_0, will generate one outcome at t_1 if the body is at rest at t_0 and a different outcome at t_1 if the body has an absolute velocity at t_0. Since the measurement process is itself a physical process, it will be governed by the physical laws, which we again assume to be the laws of NG.

With this setup in place, the argument goes as follows (see Dasgupta 2016: 855-57). Suppose we have a device, presented at t_0 with a body at rest, and with a pointer indicating a certain point *p* on a dial at t_1. We consider a boosted world *w*, in which everything has been subjected to a uniform velocity boost of 5 mph to the north. Here the device is presented at t_0 with a body travelling at 5 mph to the north. The distances between all bodies, including the distance between the measured body and the measuring device in *w* are the same as in our original world given that this remains invariant across uniform velocity boosts. Because the measurement process is itself a physical process governed by the laws of NG, and since the distances (as well as their rates of change across time) are all the same, if the device indicated point *p* on the dial at t_1 in our original world, the laws tell us that the device indicates point *p* on the dial at t_1 in the boosted world *w* as well. The absolute velocities differ therefore across the two worlds, but the indicated point on the dial remains the same. The outcome on the dial does not co-vary with the change in absolute velocity as, we assumed, is necessary for a detection of absolute velocity. Since we assumed an arbitrary measuring device, we can generalize: no device can be sensitive to absolute velocities in the way required for the observation of absolute velocities. So, absolute velocity is unobservable.

The argument seems to have the following problem. There is a perfectly sensible way in which we would be able to detect absolute velocities *if* there were absolute velocities. It is indeed the case that the *invariant* properties of the device remain the same between the original world and the boosted world. But this only shows that we cannot restrict ourselves to using invariant properties of the measuring device in the measurement of a variant property. It does not show that variant properties are unobservable as such because it does not rule out that we can use variant properties of the device to measure the variant property of the measured body; and we can.

Let us see how this would work. Assume that we have a device whose pointer only points at point *p* at t_1 if the distance between the device and the body remains the same for some time between t_0 and t_1 (thus indicating that the body was at rest relative to the device), and that it would indicate a different point on the dial at t_1 if the distance between the body and the device changes between t_0 and t_1. Imagine that in the original world, the device points at *p* at t_1, thus indicating that the body is at rest relative to the device. If there are absolute velocities, then relative velocities would consist in ratios of absolute velocities, for example, being at rest relative to another object would consist in having the same absolute velocity as that object. This means that, if there are absolute velocities, we have not been told enough about the device at t_1 at this point, not for a measurement of the absolute velocity of the measured body as opposed to a measurement of a mere ratio of absolute velocities. A further relevant feature is the absolute velocity of the measuring device. If the device is at absolute rest, then this together with its indication of the point on the dial tells us that the observed body is at absolute rest. That is, the fact that the distance between the device and the body remained the same between t_0 and t_1 tells us that the body has the same velocity as the device, and this together with the fact that the device is at absolute rest tells us that the body is at absolute rest.

Consider now the boosted world *w*. Granted: the device indicates the same point *p* on the dial at t_1. But here too, the absolute velocity of the device is relevant to the measurement. In *w*, the device is travelling at 5 mph to the north. So, in *w*, the given body is measured to have an absolute velocity of travelling at 5 mph to the north. Between the original scenario and *w*, we have different outcomes in our measurements, due to a difference in properties of the measuring device. In the first case we have the indication of *p* on a device that is at rest; in the second case we have an indication of *p* on a device that is travelling at 5 mph to the north. So there is a process that generates one outcome at t_1 when the observed body is at rest, and a different outcome at t_1 when the observed body has an absolute velocity. If there were absolute velocities, there would also be the covariance of properties of the measuring device with the absolute velocities of the measured system, which we assumed is all that is required for a measurement of the absolute velocities. The absolute velocity of the body is therefore not unobservable.

To be sure: I do not propose that we actually measure variant properties in this way. The aim is just to show that, at the point where we only know that an apparent property varies in symmetries of a certain of laws, we cannot infer that it must thereby be unobservable. After we come to know that no object instantiates variant properties, we know that no measuring device does so in particular, and hence that we cannot observe the variant properties either. We cannot assume that the device has no variant properties before engaging in the symmetry reasoning. To do so would be to assume from the start what the symmetry-to-reason should allow us to conclude: that the variant properties are unreal. At the point where we only know the variance of a property in some set of laws, there is a straightforward story about how we could observe those properties if they were real. We cannot infer their unobservability from their mere variance in the discussed paradigm case.

One might object that if the measurement devices had the variant properties then the relevant set of laws of nature would not be complete, but we assume them to be complete (Dasgupta 2016: 840). This brings us back to the issue with the redundancy account. We can only assume the laws of nature to be complete if we know already that any property that varies in those laws (and hence is not fixed by those laws) is unreal. The completeness assumption prejudges the issue and renders the symmetry-to-reality reasoning circular.

The sketched view of the would-be measurement of absolute velocity relies on the idea that, in a measurement of a determinable property F in a given body (such as its absolute velocity) we must sometimes appeal to the device's own determinate of F (the device's own absolute velocity). This may raise a feeling of unease: is this not circular or problematic somehow?

The feeling of unease is unwarranted. Consider first another illustration of this idea. I want to measure the length of a stick, using a rod. I hold the rod next to the stick and the ends of the rod align perfectly with the ends of the stick. This only tells me that that the rod and the stick have the same length, it does not tell me what the stick's length is as such. For this we need the fact that the rod's length is one meter. The length of the rod is obviously involved in the measurement of the length of the stick. It is the fact that the ends of the rod align with those of the stick *together with the fact that the rod's length is one meter*, that tells us that the stick is one meter. Consider now a transformation that renders all objects twice as long. In this enlarged world, the rod is now two meters. When I hold the rod next to the stick, and they align, this fact together with the fact that the rod is two meters, indicates that the stick is two meters. Again, nothing special here, and we have a straightforward difference in measurement outcomes between the original and the enlarged world, due to a difference in the properties of the measuring device (the rod).

Is there some general reason to think that, in a measurement of a property F in a given body (such as its absolute velocity, or length), we cannot appeal to the device's own determinate of F (the device's own absolute velocity, or length)? I do not see why. Note that if one believed that only distances are ever detected, one will also allow that we appeal to distances, such as between a pointer and a dial on the measuring device, in a measurement of the distance between the body and the device over time. If distances can be involved in measurements of distances, why could absolute velocities not be involved in measurements of absolute velocities? We should not think that this is because objects (including measurement devices) do not really have an absolute velocity, since this assumes what the symmetry-to-reality reasoning is meant to establish. We also should not think that we cannot resort to the device's own absolute velocity because absolute velocities (including those of measurement devices) are unobservable, since this assumes what the current argument is meant to establish.

We also should not worry that we face an empirical regress because we first need to measure the absolute velocity of the measuring device in order to figure out the measurement of the absolute velocity in the observed body. Again, there is no difference here between our presuming epistemic access to the distances, such as between the pointer and the dial, in a measurement of distances. We do not worry that any measurement of distances leads to an empirical regress because the distances between bits of the device must first be ascertained before we can take the device to indicate anything about the distances between two bodies. We presume access to the distances between bits of the device, and knowing these, ask what they indicate about the distances between other things. Measurements need to start somewhere. Similarly for the case of absolute velocity. If there were absolute velocities, we would presume that we have access to the relevant absolute velocity of the device, and ask what it indicates regarding the absolute velocities of other objects. To demand otherwise is to set unmotivated and indeed impossible requirements on the measurements of quantities.

Dasgupta notes that for his argument to generalize, he must assume that scenarios that are related by a symmetry transformation are in general observationally equivalent (2016: 857). To secure this, he defines symmetries as precisely those transformations that preserve the laws and relate scenarios that are observationally equivalent (2016: 866). This secures the observational equivalence of symmetries in Dasgupta's sense, by definition.[1] How do we know whether a symmetry in the formal sense is also a symmetry in Dasgupta's sense? I have argued that we cannot infer observational equivalence from symmetry in the formal sense.

One might think that – even if the argument from variance to unobservability fails - the unobservability account could still be true if the paradigm cases are all cases in which, as a matter of fact, the symmetry-related scenarios happen to be observationally equivalent. In the literature in the philosophy of physics, it seems quite a common belief that we do not observe absolute velocities (see Earman 1989: 43; Roberts 2008: 163; and Dasgupta 2016: 855). Dasgupta supports his intuition by appealing to the allegedly familiar experience that "events inside a [train] carriage look the same regardless of whether the train is at rest or in uniform (unaccelerated) motion" (2016: 855; see also Roberts 2008: 163). It seems to me that this view should be far more controversial than it actually is. I'm not convinced that experiences of moving trains support the intuition that we do not experience absolute velocities. I confess to finding it quite natural to think that, typically, the train will look to be at rest when it is at rest, and will look to be moving when it is moving; and that there is no experiential equivalence between the two cases. There is after all a phenomenal difference between an experience of yourself as being at rest and of

[1] One may be puzzled: given this definition of symmetry, why did Dasgupta gave his elaborate argument for the claim that we cannot observe variant properties if anything that varies between observationally equivalent systems is *by definition* unobservable. The puzzlement is unwarranted. The argument concerns just the paradigm case and did not help itself to the offered definition of symmetries. I think the argument fails, but not on account of being trivial.

the outside environment as moving in the backward direction, and an experience of yourself as moving in the forward direction and of the outside environment as being at rest. One might think that it is a straightforward difference in contents that explains the phenomenal contrast.[2]

If we broaden our discussion for the moment, and consider the properties that are variant in the symmetries of the special theory of relativity, the claim that variant quantities are indeed directly experienced is even more plausible. The list includes such as properties as simultaneity, length, duration, and spatial shape – all variant properties in the Lorentz transformations of the special theory of relativity. If anything, it seems prima facie plausible that we have experience of these properties.[3] When a piece of paper is square according to descriptions in one frame of reference, and oblong according to descriptions in another frame of reference (obtained from a Lorentz transformation on the first frame), it is plausible to think that the different shape properties described by the frames are properties that we experience. It seems to me that the main reason that one might have for doubting this is that one has already established that the relevant properties are not instantiated in the world via symmetry-to-reality reasoning. But this means that we cannot appeal to this in the symmetry-to-reality reasoning itself.

More importantly, however, one does not want the justification of symmetry-to-reality reasoning to be hostage to (controversial) views about what we, human beings, happen to be able to directly experience or not. Introspective judgments about when two

[2] This line of reason appeals to Siegel's (2010: Ch. 3) method of phenomenal contrast for supporting judgments concerning the contents of our perception.

[3] For discussion, see Epstein (forthcoming), who agrees, and Chalmers (forthcoming), who agrees when it comes to the co-called 'Edenic features' of experience.

experience differ or not (as in the train case) or about what we sort of properties are involved in our experience, are not plausibly involved in the symmetry-to-reality reasoning of physicists. Any reconstruction that relies on an initial assumption of observational equivalence seems to me to be an implausible reconstruction of the reasoning.

The arbitrariness account does not require any initial assumption of observational equivalence. Applied to our toy case, the reasoning was as follows. We find that there is a symmetry in the form of a uniform velocity boost, raising the question whether (1) the world conforms to one scenario, or (2) it conforms to the boosted scenario. At this point, we noted, it can be hard to see whether we experience or otherwise detect absolute velocities in the world around us – and we do not need to assume that we do not experience or detect them. If it so happens that we indeed do not detect them, we ipso facto lack a body of objective evidence for a single distribution of variant properties. But if we do experience or detect these properties, these experiences will be perspectival in the same sense in which our experiences of things as being on the left or right is perspectival. Equally good observers plausibly experience incompatible distributions of absolute velocities with no neutral ground on which to decide between them. Also in this case, then, we lack a body of objective evidence for a single distribution of variant properties. We therefore do not need to assume that we have no experience of absolute velocities, we only need to assume that such experiences do not form an objective body of evidence privileging one single distribution of variant properties. This seems to me to be a relatively weak assumption and, I submit, a prima facie plausible assumption in the paradigm cases of the symmetry-to-reality reasoning. One way or another, we face an arbitrary choice if we do not deny the reality of the variant properties in the paradigm cases.

More can be said about the nature of the threatening arbitrariness and, of course, about the justification of the reasoning so construed. The aim of this paper was to show that the proposed account is worthy of such further investigation. It is prima facie plausible and simple. It does not prejudge matters and requires relatively minimal assumptions about the type of empirical evidence we do and not possess.

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