Descartes' Forgotten Hypotheses on Motion: Kinematic Logic and Relational Transfer

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Abstract (WORD COUNT: 108)

This essay explores two of the more neglected hypotheses that comprise, or supplement, Descartes' relationalist doctrine of bodily motion. These criteria are of great importance, for they would appear to challenge Descartes' principal judgment that motion is a purely reciprocal change of a body's contiguous neighborhood. After critiquing the work of the few commentators who have previously examined these forgotten hypotheses, mainly, D. Garber and M. Gueroult, the overall strengths and weaknesses of Descartes' supplementary criteria will be assessed. Overall, despite their ingenuity, it will be demonstrated that Descartes' criteria cannot rescue his brand of natural laws from the inherent limitations of his strong relational account of motion.

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(WORD COUNT: 6706)

While nearly every aspect of Descartes' much-maligned theory of motion has been carefully scrutinized by commentators, there are a few hypotheses advanced in the *Principles of Philosophy* that have been, oddly enough, largely overlooked. Essentially, these criteria constitute an amendment to the Cartesian doctrine of "relational" motion: i.e., that motion is the reciprocal translation of a body and its contiguous neighborhood (of surrounding plenum bodies). In his neglected refinements to this view, Descartes argues that there is a way to determine which of the two reciprocally translating bodies is *really* in motion. When two smaller bodies move in opposite directions on the surface of a larger body, he explains, the kinematics of the scenario rule out the possibility that it is the larger body that is in motion. Moreover, a body is in motion if its whole surface, and not merely a portion of its surface, moves relative to its neighborhood. The importance of these "supplementary" criteria cannot be overestimated, for they would seem to compromise the "strong" form of relational motion normally attributed to Descartes.

In this essay, we will explore the Cartesian theory of motion in the light of the crucial addendum that appear in the *Principles.* Although Descartes' arguments are deficient in various ways, as will be demonstrated, the few attempts by commentators to deal with these hypotheses have not correctly diagnosed their underlying weakness: namely, their inability to consistently ground the Cartesian natural laws. While section 1 will offer a brief description of Descartes' overall theory, section 2 will evaluate the strengths and weaknesses of Cartesian motion provided his important additional stipulations.

1. Cartesian Motion

In Part II of the *Principles of Philosophy,* Descartes' provides an analysis of motion exhibiting strong relationalist overtones. In this work, which presents his most extensive discussion of this phenomena, Descartes defines motion (*motus*) as "*the transfer [translatio] of one piece of matter or of one body, from the neighborhood [vicinia] of those bodies immediately contiguous to it and considered at rest, into the neighborhood of others."* (Pr II 25)[1] As most commentators have noted, Descartes attempts to distinguish his "proper" conception of motion, as change of neighborhood, from the "vulgar" conception of motion as a change of "place" (*locus*); where "(internal) place" is defined as the situation of the body relative to some arbitrary set of, usually resting, distant bodies. (see, Pr II 10-15, 24-28)[2] A relationalist treatment of motion would appear to arise in the following manner: in Descartes' plenum universe, any attempt to stipulate that the surrounding bodies are "at rest" must remain purely arbitrary, since "we cannot conceive of the body AB being transported from the vicinity of the body CD without also understanding that the body CD is transported from the vicinity of the body AB." (Pr II 29) Hence, "all the real and positive properties which are in moving bodies, and by virtue of which we say they move, are also found in those [bodies] contiguous to them, even though we consider the second group to be at rest." (Pr II 30)

As normally interpreted, Cartesian motion is thus relational in the strict sense, since Descartes' phrase, "considered at rest" (*tanquam quiescentia spectantur*), seems to imply that the choice of which bodies are at rest or in motion is purely relative to different frames of reference. Accordingly, since different perspectives will obtain conflicting estimates of the very same bodily motion, there can be no "actual" or "absolute" determinations of that body's state of motion. Most commentators regard this strong, or "strict", form of relationalism (as we shall dub it) as Descartes' preferred hypothesis of motion, although his application proved inconsistent (Dugas, 178-179, Westfall, 57-58, Shea, 322-323, Earman, 41, Barbour, 449-450, to name only a few);

while others have suggested that Descartes' professed relationalism is, at least in part, a sop to church censorship in order to advance his Copernican brand of planetary vortex theory (e.g., Koyré, 265, Blackwell, 227).[3] D. Garber has aptly dubbed Descartes' relational theory of motion, the "reciprocity of transfer" (167), and it is not difficult to comprehend why it has remained so controversial. Not only does this hypothesis appear to reinstate a "vulgar" conception of motion, i.e., rendering motion hopelessly relative to conflicting perspectives (see, Pr II 24-28), but a strong brand of relational motion is also inconsistent with the laws of motion he advanced in the *Principles.*

As just noted, problems begin to arise for Descartes when we conjoin his analysis of motion with his dynamics of bodily interactions. In the *Principles,* for instance, Descartes advocates a series of natural laws that appear to violate relationalism by invoking determinate individual bodily states of motion: "all movement is, of itself, along straight lines. . . ." (Pr II 39) Unfortunately, it is not possible, or meaningful, to attempt to ascertain the "unique" path or trajectory of a body given his strict brand of relationalism. Since trajectories are determined relative to each observer, and all observers are in relative motion, any effort to fix the unique path of a particular moving body will result in a host of conflicting measurements, none of which can lay claim to its "actual" path. Consequently, Descartes' second law of motion (quoted above) would appear to transgress his espoused relationalism; as do many of the collision rules that spell out his third natural law (which conserves the "quantity of motion," or product of size and the scalar quantity speed, $m|v|$, of all bodies).

Furthermore, the *Principles* seemingly betrays the influence of a second non-relational factor in Descartes' rendition of bodily "modes"; where, briefly, a mode is a particular instantiation or "way" that a corporeal body manifests its spatial extension (as with "shape": see, Pr I 56, 61). Some commentators, like Gaukroger (371-377), have rejected Descartes' apparent sanction of strong relationalism based on his insistence that "movement and rest are merely two diverse modes of [a] body" (Pr II 27). According to

Garber, on the other hand, motion as a mode need not conflict with the reciprocity of transfer: "Unlike shape, motion seems to be relational; though there may be a genuine distinction between motion and rest, motion seems to be a property that pertains not to an individual, but, in a strange way, to both an individual and its surrounding neighborhood" (172; these issues will examined further below). Even granting Garber's point, a similar distinction between motion and rest is drawn in the first law of nature, where both are submitted as intrinsic, but different, natural bodily states: bodies do not tend towards rest, he reasons, since "rest is the opposite of movement, and nothing moves by virtue of its own nature towards its opposite or its own destruction." (Pr II 37) Besides revealing the influence of the Aristotelian/Scholastic logic of contrary predicates,[4] Descartes' pronouncements run afoul of relationalist doctrine, for he seems to be presuming that rest and motion are not only distinct but opposing states of bodies, a qualitative difference that cannot be captured by any strict relationalist means.

There would also seem to be distinct non-relational factors at work in Descartes' collision rules, which constitute the specific instances of his third natural law. The inconsistencies are most conspicuous in the case of rules four and five: briefly, in the fourth rule, a large object remains at rest during impact with a smaller moving body, and simply deflects the smaller body back along its path (Pr II 49); whereas in the fifth rule, a large body will move a smaller stationary object, "transferring to [the smaller body] as much of its motion as would permit the two to travel subsequently at the same speed" (Pr II 50). From a relational standpoint, however, rules four and five constitute an identical collision, since they both involve the interaction of a small and large body with the same relative motion (here, a simple speed difference) between them. Therefore, because they represent an identical scenario, the consistency of Descartes' alleged relationalism is placed in serious doubt.

D. Garber has challenged this conclusion, nevertheless, by pointing out a non-relational facet of translation that can greatly assist the Cartesian in resolving the dilemma of impact rules four and five:

> For Descartes, the case in which [a body] is in motion is physically distinct from the case in which it is at rest. And so, for him, the situations described in [rule four] and [rule five] are not mere redescriptions of one another; one cannot arbitrarily designate which of two bodies in relative motion is in motion and which is at rest. (241)

In other words, since there is a means of discerning rest from motion--translation of neighborhood or no translation--the fourth and fifth rules can thus be individuated without transgressing relationalist tenets (Des Chene 1996, makes the same point, 297-298). Or, to put it differently, while translation *per se* is relational, such that a translation does not provide a means of determining, say, which of two bodies moved, it is nonetheless a fact that a body is *really* at rest, and not in motion, if *no* translation takes place--and this fact can be put to advantage by the Cartesian. We will return Garber's important observation in the next section, but first we need to examine the details of the additional hypotheses that Descartes amended to his theory of motion.

2. Descartes' "Single Body" and "Whole Body" Displacement Hypotheses.

2.1. Exposition of the Hypotheses. The first of the refinements to his reciprocity of transfer thesis appears in Part II, Article 30, of the *Principles,* which addresses the reason "why the motion that separates two contiguous bodies is attributed to one rather than to the other." Descartes provides a lengthy example to demonstrate his point:

> We do not think that a body is moving unless it moves as a whole, and therefore we cannot understand that the whole earth moves simply for the reason that some of its parts are transported from the vicinity of other smaller bodies with which they touch; and since we frequently notice many similar transferences that are contrary to one another. For instance, if the body EFGH is the earth, and if, on its surface, body AB is transported form E towards F at the identical time that body CD is transported form H towards G; then although we know that the portions of the earth contiguous to body AB are transported from B towards A, and the action of the transference cannot be either different or weaker in the parts of the earth as in the body AB; we do not by that understand that the earth moves from B

> towards A, or from the East towards the West; since by the fact that those parts of it which touch the body CD are simultaneously being transported from C towards D, we would also have to understand that the earth moves in the opposite direction, that is, from West to East; and these two assertions are contradictory. Therefore, unless we deviate too much from the traditional manner of speaking, we should say that the bodies AB and CD, and other similar bodies, move; and not the earth. (Pr II 30)

Put briefly, the relationally symmetric translation between a body and its contiguous neighborhood is broken by the motion of two smaller bodies, in opposite directions, along the surface of a larger body. Since it is impossible for the larger body to be moving both east to west, to account for the motion of AB, and simultaneously from west to east, to explicate the motion of CD, it must be the case that the larger body is at rest. Thus, the two smaller bodies must move in opposite directions upon the surface of the resting larger body (see Figure 1).

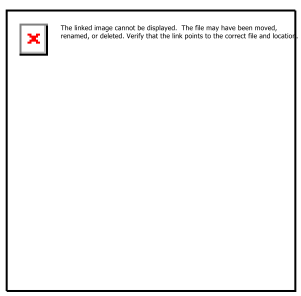

Figure 1. A reconstruction of Descartes' illustration for the example utilized in Part II, Article 30, of the *Principles.*

This criterion, which M. Gueroult (1980, 208) has dubbed "single body" displacement, constitutes an important advance in the development of Cartesian kinematics (or so it would seem at first glance). As described above, Descartes' physics requires some means of determining the individual motions of bodies if it is to remain consistent with his natural laws. Whether or not a body is at rest or in motion is a non-relational feature of Cartesian space-time, as Garber correctly notes: i.e., whether or not there is a translation, or no translation, between a body and its contiguous neighborhood is an "invariant" fact for all observers.[5] Nevertheless, the sheer fact that a body is in motion, or lacks motion, is not sufficient in itself to underwrite the Cartesian natural laws, let alone the collision rules. To ground the collision rules effectively, such as rules four and five, one needs to determine if the two bodies are approaching one another; and this property of the impact phenomenon is not captured by sole reference to the neighborhood of each individual body. Even provided relational motion between a body and its neighborhood of contiguous bodies, it is still not possible to determine which collision rule the impact will fall under, or if the bodies will even collide. Suppose, for example, that the two bodies are separated by a fixed spatial distance, and that one of the bodies is, and the other is not, undergoing a reciprocal translation with respect to its contiguous neighborhood. Given this scenario, it is not possible to determine if; (i) the "translating" body approaches the "non-translating" body, or (ii) the spatial distance between them remains fixed and the translating body simply experiences a change of neighborhood (i.e., the neighborhood moves but the body does not). Therefore, an appeal to the reciprocity of transfer thesis results in an underdetermination of the outcome of bodily collisions, as well as the capacity to apply, and make predictions from, the Cartesian collision rules.

Nevertheless, it is at this point that Descartes' single body displacement hypothesis can prove itself to be quite useful. If it is possible, following this hypothesis, to determine if a body is in motion by analyzing the motions of the smaller particles on its surface, then the underdetermination dilemma imposed by scenarios (i) and (ii) can be successfully resolved: in short, option (ii) will be eliminated because the translation of the body and its contiguous neighborhood will reveal upon closer inspection to be solely due to the motion of the neighborhood, rather than the body. That is, the larger body will manifest (possibly numerous) pairs of smaller bodies moving in opposite directions along its surface (as in Figure 1); and, with the discovery that both bodies in case (ii) are actually at rest, this scenario does not thus amount to an impending instance of collision rule four or five. There are, of course, many difficulties associated with this theory.[6] But, before assessing the success of the single body, or SB, displacement hypothesis, it will be useful to examine the second criterion that Descartes offered in striving to overcome the limitations of his theory of motion.

One of the first commentator to recognize the importance of SB displacement was M. Gueroult (1980), who also directed attention to the second Cartesian hypothesis, which he deemed, "whole body" (WB) displacement. In this addendum to his theory of motion, Descartes argues that if a translation occurs between two bodies, but only one of the bodies undergoes a change of neighborhood over its *entire* surface, then the motion must be attributed to this body (rather than to the body that only experienced a partial change of neighborhood). Descartes introduced this criterion in large part to counter the Tychonic view that placed a stationary earth at the center of the rotating planetary spheres. He reasons that only the inner surface of the planetary sphere, which is contiguous with the earth's surface, and not the sphere's outer surface (which is contiguous with the next planetary sphere in the series), experiences a change of neighborhood with respect to a translation between that inner surface and the earth. Motion should be assigned to the earth, and not the planetary sphere, since the whole surface of the earth undergoes a change of contiguous neighborhood (whereas only the inner surface of the earth-enclosing sphere changes its neighborhood in this motion). As a result, motion "must be solely attributed to the [planetary spheres] and not the planets; exactly as the partial transfer of water and air that occur on the earth's surface are normally attributed, not to the earth, but to those portions of the air and water that are transported." (Pr III 28)

Unfortunately, this new criterion would not appear to be as successful as its SB counterpart in resolving our previous problem of relational motion, for it cannot dispel the underdetermination dilemma examined above; i.e., the problem of which scenario, (i) or (ii), is the actual outcome of a translating and non-translating body (as originally specified in collision rules four and five). The WB displacement criterion cannot resolve the dilemma because the majority of the smaller particles will only experience a change of contiguous neighborhood on the side facing the larger body; and hence these smaller particles will be deemed "at rest". Put differently, since many of the smaller particles will flow together in a joint, synchronous motion (en masse)--that is, the particles will be at rest relative to one another (but not relative to the larger body)--only the sides of the particles contiguous with the larger body will undergo a "change of place". The larger body will be categorized as "in motion", on the other hand, due to the complete change of its contiguous neighborhood (i.e., all the minute particles that surround it are in motion relative to its surface). Unlike the SB hypothesis, consequently, the WB criterion will fail to identify (eliminate) instances of scenario (i) from scenario (ii). Since both cases (i) and (ii) depict a translating and non-translating body, these scenarios will be generally indistinguishable according to the WB displacement hypothesis, and thus it will be impossible to identify which one of these hypothetical scenarios is operative unless some outside frame of reference is introduced (or one simply waits until the bodies do, or do not, collide).

Of course, once an outside perspective is introduced to distinguish these impact scenarios, such as a reference frame located on one of the colliding bodies, the *conjunction* of this frame and the WB or SB hypotheses essentially equips the space-time with a privileged reference frame, in direct violation of the tenets of Descartes' strict relationalism. A strict relationalism is undermined since the supplementary criteria will uniquely determine whether the particular frame is either *really* at rest or *really* in motion (since it is attached to a body that, via the criteria, is either *really* at rest or in motion), and thus the frame can now serve as a means of procuring the same determinations of motion for all Cartesian bodies. For many a latter-day Cartesian, however, this form of "weak" (or "reference frame") relationalism may be a consistent and acceptable alternative to Descartes' more austere variety. On this weakened form of relationalism, motion is still a reciprocal relation among bodies, but there are means *other than absolute or substantival space* for determining their individual states of motion.[7] Yet, it is an open question whether or not such a relational variant is compatible with the spirit of Descartes' theory, especially when one recalls that the supplementary criteria, which were intended to shore up the difficulties in his original account of motion, askew all recourse to outside frames of reference for determining such individual bodily states. Descartes attempts to rely on a form of "kinematic logic" in these criteria, as will be discussed below, rather than on outside perspectives in resolving his relational problems. Therefore, any weakened brand of relationalism that incorporates reference frames would seem largely incompatible with the supplementary criteria put forward in the *Principles.*

2.2. Critical Response to the Hypotheses. In his important survey of these issues, Gueroult fails to notice the inherent deficiency in the WB displacement hypothesis which, as above, renders it incapable of ridding the Cartesian natural laws of relationalist obstacles. Rather than assess the criteria in this straightforward manner, i.e., on their ability to measure individual bodily motion, Gueroult ultimately judges their success against the backdrop of a deeper "definitional" puzzle that lies at the heart of Cartesian kinematics (which is the study of the motions of bodies regardless of force). In the *Principles,* Descartes stipulates that motion is the reciprocal translation of a body and its neighborhood, yet he then proceeds to stipulate that "by *one body,* or *one part of manner,* I here understand everything which is simultaneously transported". (Pr II 24) To avoid the intrinsic circularity of this approach to the phenomenon of motion, Gueroult reasons--correctly, it would seem--that Cartesian natural philosophy must presuppose an additional hypothesis that grounds the cohesion of the parts of extension (matter):

> What is required is a property that grounds--outside of all relativity [of the definitions, as above]--*displacement as a whole* [WB] and *single displacement* [SB]. This property is cohesion. Cohesion is due to the *rest of its parts,* as the *force* of rest, the force of resistance to the motion that would disaggregate them. If, thanks to this force, we can break the circle of relativity and reach the absolute of a science that is certain, it is because we have, by the same stroke, left purely

> geometrical [kinematical] concepts in order to raise ourselves to a dynamical concept--that of *force of resistance to motion*--which goes beyond these. (212)

The "resistance to motion" manifest by Cartesian bodies, and implicitly at work throughout the collision rules, is thus singled out by Gueroult as the preferred solution to the "relativity", or circularity, of Descartes' definition of motion. Put differently, Descartes ultimately appeals to the dynamical aspects of motion to solve the riddle imposed by his haphazard kinematic descriptions (where "dynamics" refers to the motions of bodies under the action of forces). Gueroult's analysis of the dynamic factors implicated in Descartes' work may be correct,[8] but it does not address the question of the potential success of these additional criteria in resolving our original problem of relational motion and the Cartesian natural laws. As presented in the *Principles,* these criteria were intended to provide a purely *kinematic* means of determining the individual motions of bodies for his physics. Moreover, the relational compatibility of Descartes' natural laws remains a serious problem *regardless* of the deeper circularity of the Cartesian definition of "motion" and "body". Gueroult does not critique this aspect of the criteria; therefore, after discussing some objections raised by Garber, we will need to return to the question of their overall success in answering the relational motion puzzle.

In response to Gueroult, Garber contends that the intended purpose or rationale of the supplementary criteria has been greatly misconstrued (1992, 346-348, fn. 12). As regards the SB displacement hypothesis, he argues that the context of the discussion strongly implies that it was invoked in order to explain our "common beliefs" about a reciprocal transfer between the earth and the object on its surface. In other words, the criterion was not designed to challenge the concept of reciprocal translation by procuring a means of determining which body is, or is not, in motion. Rather, the criterion merely constitutes a useful expedient in accounting for why we *think* that it is really the earth that is at rest. The "proper" view of motion, however, deems the translation to be reciprocal, so that attributions of rest or motion are purely relative once a motion occurs. Garber backs up this claim by recalling that Descartes prefaces his discussion of the criteria by stating that the reciprocity of transfer "clashes . . . with the common way of speaking" (Pr II 29), but later insists that "meanwhile we must remember that everything that is real and positive in moving bodies . . . is also found in the others contiguous with them." (Pr II 30) Descartes makes similar pronouncements with respect to the WB displacement hypothesis that appears in Part III, where "the transfer [of the earth and the heavens] gives us no reason to attribute motion to the heavens rather than the Earth." (Pr III 38)

Garber's arguments are quite persuasive, but it is not clear that Descartes only intended his supplementary hypotheses to explain away our common perceptions of reciprocal translation. It is conceivable that the criteria both explain our perceptions of the phenomena, and, in addition, really do provide a means of determining the individual motions of bodies. In fact, in his exposition on planetary motion in Part III, Descartes occasionally refers back to the criteria in a manner that suggest they are much more than a mere expedient to account for common misperceptions. For instance, directly after the quote from Pr III 38, cited by Garber above, Descartes declares:

> Moreover, in accordance with what was stated earlier, this motion [of earth and heaven] should only be attributed to the Earth; because the separation occurs over its whole surface, and does not similarly occur over the whole surface of the heaven but only over the concave portion contiguous to the Earth.

The reference to "what was stated earlier" concerns the crucial issue of the earth's proper motion, or lack thereof, as it sits in its band of circling plenum particles (that is, crucial for his relationship with the Church censors). In (Fr) Pr III 28, he invokes the WB displacement hypothesis to deal with this potential difficulty:

> In the common usage, all action by which a body travels from one place to another is often called motion; and in this sense of the term it can be said that the same thing is both simultaneously moved and not moved, depending on the different ways we determine its location. It follows from this that no movement, in the strict sense, is found in the Earth or in other Planets; because they are not transported from the vicinity of the parts of the heaven immediately contiguous to them, if we consider these parts of the heaven to be at rest. Since, to be transported in this way, they would have to be simultaneously separated from all the contiguous parts of the heaven, which does not happen. However, because the

> matter of the heaven is fluid, sometimes some of the particles, and sometimes other particles, move away from the Planet with which they are contiguous, and this is a movement which must be attributed solely to the particles and not the Planet. . . .

In this passage, Descartes contrasts the "common" with the "strict" sense of motion (as initially discussed in Part II), and seems to argue that the reciprocal translation of the earth and some of its contiguous particles falls under the latter meaning of the term. The earth's lack of motion, and the motion of some of the contiguous particles, is motion in the "strict sense" because the earth is not, and a small number of particles are, transported from *all* of their contiguous neighbors. Consequently, at least in this passage, the WB displacement hypothesis is included within Descartes definition of the "strict sense" of the earth's motion. Needless to say, this passage (if interpreted correctly, here) would seem to contradict outright Garber's contention that the criteria were only meant to explain the "common sense" understanding of motion. Moreover, as is also evident in this context, Descartes needs both the SB and WB displacement hypotheses in order to satisfy the Church censors. Without a *literal* construal of these criteria, a motion between the earth and a body located on its surface could be legitimately ascribed to the former, and thus directly challenge the Church ban on terrestrial motion.

Furthermore, it is not the case, as Garber also contends (1992, 348), that the WB displacement hypothesis is only mentioned in Part III of the *Principles.* Not only is it crucial for other sections in this Part, i.e., the analysis of the earth's motion in Pr III 28, as examined above, but it also appears at the beginning of his discussion of the SB hypothesis in part II: "we do not think a body is in motion unless it moves as a whole, and therefore we cannot understand that the whole earth moves simply since some of its parts are transported from the vicinity of some other smaller bodies which touch them; . . ." (Pr II 30) Indeed, the joint presence of the criteria in this Article is powerful evidence of their close interconnection. One might interpret the SB thesis, along these lines, as a particular instantiation of the more general WB hypothesis: since the two smaller moving bodies on the earth's surface exchange their entire contiguous neighborhood, while the stationary earth does not, the SB displacement hypothesis thus confirms or validates the broader WB displacement thesis. (Gueroult also notes the various interrelationships of these criteria; 1980, 210-212.)

It may still be objected, however, that Descartes' insistent reminder that motion is a reciprocal translation (of body and contiguous neighborhood) necessarily blocks any literal reading of the supplementary criteria. As Garber would undoubtedly point out, it is difficult to reconcile a strong brand of relationalism with a set of hypotheses which effectively breaks the symmetry of the relation. Yet, Descartes may have attempted to make the following, fairly subtle, distinction: although motion is a purely reciprocal *kinematic* translation, there are occasions when the "logic" of the kinematic events necessitates a breaking of the symmetrical translation, thus procuring individual states of bodily motion. In the SB displacement scenario, for instance, to ascribe motion to the earth is to ascribe a mutually *contradictory* state of affairs simultaneously to the same body. Generally, motion is a reciprocal translation, i.e., as a default view, but certain logically conflicting arrangements of transferring bodies can break the symmetry, as in the SB case. On this interpretation, Descartes' theory of motion would seem to resemble Leibniz', who also favored a purely relational, kinematic account of motion, but invoked non-kinematic elements to secure the determination of individual bodily motions. In the "Discourse on Metaphysics", he states:

> For considering only what it means narrowly and formally, that is, a change of place, motion is not something entirely real; when a number of bodies change their position with respect to each other, it is impossible, merely from a consideration of these changes, to determine to which of the bodies motion ought to be ascribed. . . . But the force or the immediate cause of these changes is something more real, and there is a sufficient basis for ascribing it to one body rather than another. This, therefore, is also the way to learn to which body the motion preferably belongs. (Leibniz 1970, 315)

In a like manner, Descartes tried to procure a means of determining individual bodily motions. Yet, whereas Leibniz turned to an internal dynamic factor, Descartes introduced a set of uniquely kinematic criteria--a sort of "kinematic logic"--in order to break the symmetry of the reciprocal translation mandated for the success of his natural laws.

Overall, the above reconstruction has at least one key advantage over rival interpretations of the criteria: namely, it strives to accommodate both threads in Descartes' analysis of motion--the symmetry of translation *and* the criteria for determining individual bodily motions. The content of the discussion in Pr III 28 is of primary importance for this interpretation, needless to say, since it apparently contradicts Garber's claim that the supplementary criteria are not concerned with the proper, or strict, sense of motion (as change of neighborhood). Of course, the lack of any additional evidence supporting our construal of the criteria is a very real problem. Yet, Descartes' neglect of this particular issue in his later work entails that Garber's reading (or any other reading, for that matter) suffers a similar fate.[9] All told, to accept Garber's conclusion that the criteria only concern our "vulgar" or common understanding of motion would seem to reduce Descartes' intricate hypotheses to the same sort of political expedient that Koyré and Blackwell attribute to Descartes' overall theory of relational motion--that is, the criteria are useful for placating the Church's ban on terrestrial motion, but they should not be taken seriously as integral components of Descartes' natural philosophy.

2.3. Final Assessment of the Hypotheses. In the preceding section, we detailed the shortcomings of the previous interpretations of Descartes' supplementary criteria of bodily motion. However, we have yet to provide the final verdict on his ambitious attempt to delimit the individual motions of bodies (without violating the tenets of his strict relationalist reciprocity of transfer theory). By way of conclusion, therefore, we will turn once again to the problematic case of collision rules four and five in order to bring to light the strengths and weaknesses of the hypotheses.

As demonstrated, the WB displacement hypothesis fails to discern cases of type (i) from cases of type (ii), although the SB hypothesis can make this distinction. Nevertheless, information on the individual motions of bodies is not sufficient in itself to rescue Cartesian physics from the clutches of underdetermination. To illustrate this point, consider one of the examples that Descartes employs to explain the third collision rule: "if [body] B had initially been traveling at six degrees of speed, and [body] C at four degrees of speed, both would subsequently move towards the left at five degrees of speed" (Pr II 48). Harmonizing relationalist doctrine with this sort of physical explanation is, indeed, a rather daunting task; but, for our purposes, attention should be focused upon Descartes' concept "degree of speed". All in all, it is difficult to see how the events represented in this impact rule, as in all the others, could be consistently explicated by appeal to anything less than a reference frame for measuring the bodies' speeds relative to one another. The determination of individual bodily motion by the SB displacement hypothesis is of no use, either; since, if the speed of the colliding bodies were a measure of reciprocal translation alone, then odd situations would arise wherein the approach speeds of bodies differed from their reciprocal translation speeds. For instance, returning to Descartes' example, although body B only approaches C at, say, one degree of speed, the "rate of neighborhood change" due to a joint or dual motion of both B and its neighborhood results in a local reciprocal translation speed of six, matching the example. This possibility is somewhat disturbing, for what would happen in such situations? If the outcome of the collision were only dictated by the change of neighborhood speeds, than the respective neighborhoods of our two bodies would need to instantaneously harmonize their divergent motions to guarantee the outcome as mandated by rule three. And, requiring such long-range, let alone mysterious, cooperation from the Cartesian plenum would appear to be rather farfetched. Finally, and even more importantly, the context and elaboration of the collision rules strongly supports the common notion of an approach speed, and not rate of translation of neighborhood. The evidence favoring an approach speed is abundant throughout Descartes' exegesis: e.g., the fourth rule, where he stipulates that B could never move C "no matter how great the speed at which B might approach C" (Pr II 49).

Despite Descartes' best efforts, consequently, his supplementary criteria of motion cannot be reconciled to his laws of nature. What the natural laws require is a set of relationally consistent reference frames to ground the measure of individual bodily motions, a point which Garber also ultimately concedes: "without a common framework in which to conceive of the relative motions of more than one body, it is difficult to see how we could give an adequate treatment of the phenomenon of impact" (171). Yet, if this difficulty is acknowledged, then Garber's aforementioned claim that impact rules four and five are not inconsistent (241) is technically correct, but rather misleading. Essentially, the underlying intent or goal of Descartes' supplementary hypotheses, according to Garber, can be given the following reconstruction: because it is a fact that a body is, or is not, translating with respect to its contiguous neighborhood, there is a real distinction between the stationary earth and an object moving on its surface, or between rules four and five. This intuitively palatable conclusion thus resolves the difficulties associated with relational motion. Yet, this is only half of what is needed. Although a body at rest (not translating) is an invariant feature of Descartes' physics, the individual motion of the body is not an invariant once a translation occurs--and Cartesian physics mandates a consistent measure of these individual bodily motions (which is the aforementioned other needed half). Put differently, even granting the reality of Cartesian motion, a relative motion is ambiguous as regards the individual components of motion (see section 1), and the natural laws *require* such individual determinations for their correct *application.*

3. Conclusion

Overall, it is this deficiency of Descartes' supplementary criteria--i.e., not providing a means of determining individual components of motion via some outside reference frame--that has not been properly diagnosed by previous commentators. Yet, as we have seen, a thorough examination of the criteria can reap the commentator many unexpected rewards. Not only do Descartes' criteria bear witness to his deep insights into the complex and problematic concept of relational motion, but they even anticipate the more successful strategies of later relationalists, like Leibniz. A host of latter-day relationalists can easily sympathize with Descartes' dilemma, and admire his attempted solution, even if his proposed kinematic means of determining individual bodily motions ultimately fails to ground his particular set of natural laws.

ENDNOTES

1 Descartes, 1983. Translations from the *Principles* are based on Miller and Miller but are checked against the Adam and Tannery edition of the *Oeuvres de Descartes* (1976). I will identify passages according to the following convention: Article 15, Part II, of the *Principles* will be labeled "Pr II 15." Passages from the French translation of 1647 will be prefaced by "Fr". Other translations that are based on the Adam and Tannery will be marked, "AT", followed by volume and page number.

2 Descartes' definitional distinctions are somewhat haphazard, to say the least, for he also characterizes "external place" as the surface of the containing bodies, thereby rendering this new idea practically equivalent to his neighborhood concept (as Garber also concedes, 346, fn. 11).

3 By defining motion as change of "neighborhood", Descartes could thus claim that the Earth remained at rest in its band of vortex particles (since the contiguous particles did not change), as required by Church doctrine, yet still claim that this band *as a whole* moved around the sun. See, Pr III 28-29. I agree with Garber (186-188) that Descartes' theory of motion in the *Principles* is his genuine view and cannot be simply reduced to a political expedient.

4 That is, by declaring these states intrinsically or fundamentally "opposite" or "contrary" (as it can be interpreted from the French or Latin), Descartes reasons that motion and rest are mutually exclusive phenomenon that cannot transform or change into the one another when isolated from external influences. For a complete discussion of the role of the Scholastic logic of contraries in Descartes' natural philosophy, see, Damerow, 82-91.

5 For more details on the structures of the various renditions of a Cartesian space-time, see Slowik 1997, 1999.

6 A problem which comes immediately to mind is the general implausibility of requiring all moving bodies to manifest two oppositely-moving bodies upon their surfaces. Nevertheless, such seemingly extravagant demands are made in other places with respect to similar worries: i.e., the requirement that all bodily motions form part of some great circle of simultaneously moving bodies (in order to prevent the possible formation of a vacuum?); Pr II 33.

7 See, Slowik 1997, 1999, on Descartes, and Earman 1989, in general, for an evaluation of the viability of alternative formulations of relational space-time theories.

8 See, E. Slowik 1999, for a analysis of Cartesian motion that likewise points out the important role of dynamics in coming to terms with Descartes' kinematics. However, Gueroult seems to hold that the "force of resistance" can be simply inferred from the speed of the striking body (1980, 202). Yet, as explained in Slowik 1999, "speed" is one of the relational, perspective-dependent properties of Descartes' physics (due

to its obvious close connection to Cartesian "motion"); thus it would seem that the "rest force" should be seen as the more primitive notion, here, with speed the derived concept (via a reference frame "objectively" established by the postulated rest force--the invariant status of Cartesian "rest" providing the main work, of course). In short, the unique impact *behavior* of Cartesian bodies, which appears to invoke a resting force (but need not be interpreted as a *real* force inside the body), can serve as a basis for providing a consistent relationalist set of reference frames for measuring speed. As Argued in section 2.1, however, such reference frame procedures for rescuing Cartesian physics are problematic in that they seem incompatible with Descartes' strict relationalism and the basic nature of the supplementary criteria.

[9] As noted by Des Chene (1996, 266, fn. 11), Henry More believed that the discussion of the SB displacement hypothesis in Pr II 30 proved that Cartesian motion is not a symmetrical translation, and said as much in one of his many letters to Descartes (AT V 385). Unfortunately, and possibly of great significance, Descartes never provided a direct response to More's questions pertaining to this particular Article (i.e., Pr II 30).

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