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Authors note: Very unfortunately and for reasons I cannot now understand, I repeatedly call acceleration a 'scalar vector' (an oxymoron). This is not a device to carefully craft a paradox, but a mistake. Fortunately it does not affect the reasoning in the paper, it only causes confusion to those who know scalars to be a quantity without direction and vectors to be a quantity with direction.

IS THERE A PROBLEM OF ACTION AT A TEMPORAL DISTANCE?[1]

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It has been claimed that the only way to avoid action at a temporal distance in a temporal continuum is if effects occur simultaneously with their causes, and that in fact Newton's second law of motion illustrates that they truly are simultaneous. Firstly, I point out that this interpretation of Newton's second law is problematic because in classical mechanics 'acceleration' denotes a scalar vector. It is controversial whether scalar vectors themselves are changes as opposed to properties of a change, and therefore if they can count as effects. Secondly, I argue that the problem of action at a temporal distance is generated by the assumption that forces operate on their effects, but that this assumption is not easily reconciled with Newton's third law of motion, which is best read as saying that forces operate between objects. On that reading, there is no problem of action at a temporal distance even in a temporal continuum just as long as interacting objects coexist.

I. INTRODUCTION

In 'Causation as Simultaneous and Continuous' (Huemer & Kovitz 2003), Michael Huemer and Ben Kovitz argue that the laws of classical mechanics, in particular Newton's second law of motion, $F = m \cdot a$, depict effects as occurring simultaneously to their causes. According to Huemer and Kovitz, the advantage of a *simultaneous* view of causation, over the view that causes occur before their effects, i.e. the *sequential* view, is that it allows time and temporally extended processes to have the mathematical structure of the continuum, without action at a temporal distance.

The problem of action at a temporal distance in a temporal continuum is the following. According to the sequential view, causes and effects occupy different moments of time. Therefore, the contiguity of cause and effect requires that time be composed of a series of non-divisible moments of time, where immediately following the moment occupied by the cause, there is only one next moment, notably that occupied by the effect; if they are separated by an ever so slight temporal interval, there is action at a

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temporal distance. If, on the other hand, time is assumed to have the structure of the continuum, there are always an infinite number of moments between any two moments, in which case cause and effect are always separated by an infinite number of moments and we have action at a temporal distance. Of course, the underlying assumption is that action across ‘temporal gaps’ just like action at a distance would be a breach of the principle of locality, i.e. that things can only affect those other things that are in their immediate vicinity. According to Huemer and Kovitz, the only way to avoid action at a temporal distance in a temporal continuum, is if cause and effect occur simultaneously, and they argue that classical mechanics indeed depict them as simultaneous.

In this paper I will, firstly, argue that it is difficult to draw definite metaphysical conclusions about the temporal relationship between causes and effects from the second law of motion. Secondly, I will argue that the problem of action at a temporal distance is based on the view that causes act on their effects, which is not easily reconcilable with classical mechanics. In other words, it is based on the assumption that, say, locomotives act on the *acceleration* of a railroad car, instead of producing that acceleration by acting on the *railroad car*. To my mind, Newton’s laws of motion, in particular the third law of motion, $F_{1\ on\ 2} = -F_{2\ on\ 1}$, is best understood as describing forces as operating between objects, not events. It says that for any force exerted by object 1 on object 2, object 2 simultaneously exerts an oppositely directed force of equal magnitude on object 1.

As I read Newton, acceleration (the effect) is the product of forces operating between two objects, A and B, while on the view presupposed by Huemer and Kovitz, the acceleration is the product of an action by an object A on B’s acceleration. Only the latter view, I argue, contains the problem of action at a temporal distance in a temporal continuum.

2. PRELIMINARY REMARKS AND DEFINITIONS

When discussing the philosophical impact of physical theories, it is necessary to clarify that certain terms, which have a familiar connotation for laymen, have been given another and more strict technical definition in physics. For the purposes of this discussion concerning classical mechanics the following terms are of special interest: ‘cause’, ‘effect’, ‘action’, ‘reaction’, ‘acceleration’, and ‘interaction’. In this section I will briefly comment on these notions, but a more detailed discussion follows in section 4 and 5. Firstly, one should note that classical mechanics only deals with a certain type of cause, notably the exertion of *forces* by macroscopic material objects on other macroscopic material objects, and a certain type of effect, the changes in motion produced by these forces, i.e. *acceleration* (includes also deceleration). More precisely, the causally relevant phenomenon described by classical mechanics is called ‘stress’, the mechanical interaction between two portions of matter, typically illustrated by the collision of billiard-balls. It says nothing about, say, the causal process involved in how plants produce energy by photosynthesis, or how an intentional agent initiates actions in order to accomplish certain ends.

Secondly, in philosophy and in everyday use the term ‘action’ is used for a variety of things, not all of which are pertinent to the discussion of the simultaneity of cause and effect as described by the second law of motion. It is used to denote all kinds of bodily motions, and even purely mental activities, of which only a portion actually involves the exertion of force by a body on another body in order to change the motion of the body acted upon. For instance, one may call the entire swing of a tennis racket the action of striking the ball, but it is only during a tiny second of that swing that the racket really exerts any influence on the ball, notably when the racket touches the ball. The kind of action relevant to a discussion of the second law is only this exertion of force (impressed force) of one body (e.g. racket) on another (e.g. ball). However, even in physics the term is sometimes used in more than one sense. ‘Action’ has also been used for the integral of the kinetic energy of an object, which has nothing to do with any influence exerted by the object on anything else.[2] I will here use the terms ‘action’ and ‘cause’ interchangeably, but only in the sense of exertion of force, and the terms should not be understood in any broader sense than those pertinent to classical mechanics. Strictly speaking, then, the discussion in this paper only deals with the relationship between the exertion of force (action) by a material body on another material body and the produced change in motion (acceleration).

Thirdly, the term ‘interaction’, in the mechanical sense, should not be confused with what that term usually refers to outside mechanics, notably communication. Communication involves a successive exchange of influence (information), e.g. when A first addresses B, then B responds, and A may then again retort, and so on. Interaction, or stress, in classical mechanics is the completely reciprocal influence that two objects exert on each other when they come into contact with each other, in accordance with Newton’s third law of motion.[3]

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[2] Heinrich Hertz notes that the name ‘action’ for the integral of the kinetic energy is often condemned as unsuitable (1956, p. 228).

[3] Gravitational forces do not involve contact, according to Newtonian mechanics. They act at a distance. In other respect gravitational interaction comply precisely with the laws of motion being discussed, within the conditions in which classical mechanics is thought to hold good.

The difference between the everyday use of the term ‘interaction’, and the technical use of classical mechanics can be described by the use of a somewhat construed example. When A slaps B in the face and B subsequently slaps back, we have a case of ‘communicative’ interaction involving the two successive slaps. In classical mechanics, interaction refers to the mutual and completely reciprocal influence that A’s hand exerts on B’s cheek, and that B’s cheek exerts on A’s hand (the resistance of the cheek to the hand) when hand and cheek meet. At exactly the same time as A’s hand exerts an influence on B’s cheek, B’s cheek exerts an oppositely directed influence of exactly the same magnitude on A’s hand. As far as classical mechanics goes, there is no difference between an interaction between a moving body and a body at rest, or two identical bodies moving at the same velocity in opposite directions.

From now on the reader is asked to keep in mind the relevant mechanical connotations of ‘cause’ and ‘effect’, i.e. ‘action’, in the sense of exertion of force, and ‘acceleration’ (about which there is more to be said along these lines in section 4), as well as ‘interaction’ as denoting the phenomenon of stress, not communication.

These preliminary distinctions appear to severely restrict the scope of this discussion, and one should therefore consider how much weight should be given to its results concerning the question whether causes and effects in general are simultaneous or not. Not least in light of the fact that classical mechanics is now in many ways an outmoded physical theory. My immediate answer is: quite a lot. Classical mechanics is still recognised as a theory accurately describing the interactions of ordinary middle-sized objects moving at moderate velocities, even though it has been shown to fail for extremely massive objects, objects moving at extreme velocities, and for the quantum realm. Whatever classical mechanics has to say about how ordinary things behave should therefore be taken seriously by philosophers. According to what is called the *correspondence principle*, the relativity and quantum theories are more general theories, which must yield the same results as classical mechanics when applied to the conditions in which the classical theory is known to hold good (Weidner & Sells 1968, pp. 13-14; Albert 1992, pp. 43-44). Consequently, whatever these theories predict about very small and very fast moving entities, they ought to predict that ordinary middle-sized objects moving at moderate velocities behave like classical mechanics say they do.

If classical mechanics, as applied to the conditions in which they are known to hold good, is best understood as saying that actions and accelerations are simultaneous, then, according to the correspondence principle, relativity and quantum theories should yield the same result within those same conditions. Consequently, philosophy will be hard pressed not to accept the more general conclusion that causes and effects are simultaneous, *if* it turns out that this is how classical mechanics describe the relationship between the actions of ordinary middle-sized objects and the accelerations they produce. Interaction between material objects are after all paradigmatic examples of causes and effects in philosophy, e.g. the making of an impression in a pillow by a leaden ball, the pulling of a railroad car by a locomotive, and the breaking of a window by a brick. If it were successfully argued that classical mechanics describes accelerations as occurring simultaneously to the actions that cause them, this would be an extremely forceful argument for the point that causes in general are simultaneous to their effects.

3. THE SIMULTANEOUS VS. THE STAGGERED VIEW OF CAUSATION.

The sequential view is firmly entrenched in the common sense conception of causation, and yet it is not difficult to find everyday examples that appear to involve simultaneous causation:

1. When a leaden ball is dropped onto a pillow, a hollow is produced in the pillow at the very same time as the ball pushes into the pillow. The push of the ball and the making of the hollow appear to be simultaneous (Kant 1787, sect. A203).
2. When a door is opened, the door opens at the same time as it is pulled open.
3. When a locomotive pulls a railroad car, the railroad car moves at the same time as the locomotive pulls (Taylor 1973, p. 35).

These examples seem to involve changes that are produced simultaneously to the actions that produce them, and therefore pose a serious threat to the sequential view.[4]

The standard objection to the simultaneous view is to argue that when scrutinised in detail it turns out that the effect is ever so slightly retarded in respect to the cause. Huemer and Kovitz call this the *Staggered View of Causation*. For instance, Richard Taylor has argued that because no object is perfectly rigid, then when a locomotive begins to pull a railroad car, there will be some stretching of the coupling between the locomotive and the railroad car before the railroad car starts moving. Thus the railroad

[4] This threat was recognised already by Kant (surely influenced by Newton's *Principia* published in 1687), and provokes a long treatment of it in the second analogy of experience concerning succession in the field of appearances in accordance to the law of causality. His answer is that the "great majority of efficient natural causes are simultaneous with their effects, and the sequence in time of the latter is only due to the fact that the cause cannot achieve its complete effect in one moment. But in the moment in which the effect first comes to be, it is invariably simultaneous with the causality of its cause" (1787, sect. A202ff). In effect Kant argues that cause and effect are simultaneous, very much in the way Huemer and Kovitz argue, but that there is a temporal order between cause and effect in the sense that the effect remains after the cause has ceased to exist. There remains a hollow in the pillow after the ball has stopped pushing into it.

car will start moving a moment later than the locomotive starts pulling Taylor (1973, pp. 35-36).[5] Huemer and Kovitz discuss other examples whose explication falls under other disciplines of physics than classical mechanics. However, I will confine myself to the realm of classical mechanics, partly because of my own limited knowledge of physics, and partly because Huemer's and Kovitz's main argument for a simultaneous view is based on an interpretation of classical mechanics.

According to Huemer and Kovitz, the staggered view is falsified by classical mechanics. They claim that Newton's second law of motion is the most basic expression of causation in classical mechanics, and clearly illustrates the simultaneous relationship between cause and effect. The law says that a body's acceleration is proportional to the force exerted on it and inversely proportional to the body's mass. Huemer and Kovitz illustrate the significance of this law with an example involving a collision between two balls. The balls deform slightly when they collide and the magnitude of the forces between them increase as the deformation increases, and then decrease as the balls return to their original shape. Huemer and Kovitz claim that it *follows* from the second law of motion that one body's action on the other is simultaneous with the latter's acceleration and compression, and hence that cause and effect are simultaneous.

I am not as sure as Huemer and Kovitz are in thinking that the second law of motion is the most basic expression of causality in classical mechanics, and I hesitate to draw from it definite conclusions about the temporal relationship between the exertion of a force (an action) and a change in motion of the body acted upon. I think it is the third law about the equality of action and reaction, if anything, which is the most basic expression of the nature of causality that can be found in classical mechanics. The third law can at least teach important lessons concerning the problem of action at a temporal distance, but more about that in section 5 below.

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[5] I think Taylor misunderstands the phenomenon of stress, as described by classical mechanics. Assuming that the locomotive exerts no force on the railroad car until the coupling is stretched taut, then the prior motion of the locomotive is not strictly speaking an action on the railroad car. In accordance to the distinctions drawn earlier in the main text, the motion of the locomotive up until it actually exerts any force on the railroad car could be described as an 'action' only in the sense of being the integral of the kinetic energy of the locomotive during that period of time, but which has no influence on the railroad car. However, as soon as the coupling is stretched taut, the railroad car will exert the very same influence (measured in Newtonian forces) on the locomotive as the locomotive exerts on the railroad car.

4. IS THE SECOND LAW OF MOTION AN EXPRESSION OF CAUSALITY?

It seems to me that there is a problem with Huemer's and Kovitz' claim that the second law of motion expresses the truly *simultaneous* nature of the relationship between cause and effect. This problem primarily concerns the ontological interpretation of the second law, not the claim that causes and effects are simultaneous. I have strong sympathies for the latter claim, but I doubt that it can be supported merely by an appeal to the second law. The problem is, as I see it, that they think it is unproblematic to interpret the second law as relating 'exertion of force' by an object A on another object B, to B's 'change in velocity', which is what we intuitively understand acceleration to be, and which easily fits to standard ideas about cause and effect. An effect is a change in something, and a cause is what made that change come about. However, Huemer and Kovitz do not discuss the fact that 'acceleration', as defined by classical mechanics, is a scalar vector and that the ontological status of scalar vectors is controversial.

The core of the problem at hand therefore concerns the ontological interpretation of scalar vectors. Ingvar Johansson (2005, ch. 7.2), John Bigelow and Robert Pargetter (1989), and Frank Arntzenius (2000) have discussed the problems concerning the ontological interpretations of scalar vectors. I will not add anything of importance to their discussion, but argue that their conclusions threaten the idea that the second law of motion should be read as a basic expression of causality. Very briefly, a scalar vector is arguably not a change in velocity, but a *property* of a change in velocity, or a tendency/disposition to velocity change; it denotes the direction of a velocity change on a given scale over time (increase or decrease in m/s^2). Such a property can exist instantaneously, but is, arguably, for its existence dependent on a change in velocity between two times, i.e. it is a momentarily existing property (or tendency) of a temporally extended change.

Admittedly, it comes very natural to read '$F = m \cdot a$' as an expression of a causal relationship between a change in motion (change in the velocity of an object) and the cause to that change (an impressed force). According to this reading the law says that forces cause changes in velocity. But, this natural reading is problematic once it is pointed out that there is a discrepancy between the commonsense view of acceleration and how this term is defined in classical mechanics. Acceleration is intuitively understood as a *change,* notably a change in motion. More precisely, it is understood intuitively as a change in the velocity of an object *over time*. However, the scalar vector 'acceleration' as defined by classical mechanics, gives us the *rate* of this change, and it is a controversial issue whether scalar vectors in general should be understood as changes as opposed to an instantaneously existing properties of a change (see e.g. Johansson 2005, ch. 7.2; Bigelow and Pargetter, 1989).

It is relevant to note at this stage that acceleration is calculated in two different ways. On the one hand, it can be calculated as the *average* rate-of-change-of-velocity. This gives an approximate value of how much an object changes its velocity during every second of a longer interval (given in meters per second per second, m/s^2). Although there is ample time for a genuine change in velocity during a second, an average value is not a good stand-in for the real change occurring during any particular second. It would be absurd to claim that an impressed force produces an approximate value of a change. The average acceleration is an approximation of how much the thing changed its velocity during each particular unit of time in a longer interval, on the basis of information about the initial and final velocities of that time interval. When dealing with uniform acceleration this method will give accurate values. Not so for non-uniform acceleration, in which case it is more appropriate to calculate the exact value of acceleration for an infinitesimal period of time.

When acceleration is calculated for an infinitesimal period of time we do seem to have at least something in the neighbourhood of representing the real thing, not just an approximation of it. This presents us with the real philosophical challenge. In order to interpret instantaneous acceleration as a change, one must allow a thing to change velocities at an instant and that threatens to introduce paradox. Should we allow that an object can have two different velocities at the same time? But, should we really expect instantaneous acceleration to be a change? I think the connotations of ordinary language play tricks with us here. The term ‘instantaneous acceleration’ immediately calls to mind the idea of an object that changes velocity during an infinitesimal period of time. But I seriously doubt that this idea should come to the fore, when we strictly hold on to the idea that ‘acceleration’ is a scalar vector, i.e. the rate-of-change-of-motion. This scalar vector could be admitted to exist in an instant, and be a real property of the object, even though the object does not undergo any change in velocity during just that infinitesimal period of time. It could then be interpreted as the tendency of an object, at any given infinitesimal time point, to change its velocity in the immediate future. However, if the scalar vector is assumed to be the *relata* proper of the second law of motion, it is not clear whether the law is an ontologically basic expression of causality since then it only states that the *magnitude* of a force is at any given time proportional to the *rate*-of-change-of-velocity. It does not strictly speaking say that a force of a given magnitude *produces* a proportionate instantaneous change in velocity, inversely proportional to the mass of the accelerating object, but merely that the magnitude of the two variables *F* and *a* are at any given time proportional. On this reading the relationship is functional, not causal.

Vectors, when given realist interpretations, are understood as expressions of certain aspects of more basic phenomena (Johansson 2001). A motion vector is a property of a motion, representing the rate of that motion (velocity) and its direction. Acceleration, interpreted as a scalar vector, is a property of a change in the motion vector; it represents the rate and direction of that change on a given scale (faster or slower in m/s^2). That they are not strictly speaking a change can be seen by the fact that a hand pressed down on a table has a motion vector without really undergoing any change of motion. That the hand has a motion vector when it presses down on the table, even in the absence of a change in motion, can be seen by the fact that if the table suddenly disappeared the hand would move downward. This would not happen if the hand merely touched the surface but did not press upon it. Here the motion vector is best interpreted in terms of a tendency or disposition to move, but not as the motion itself, and likewise, *mutatis mutandis* for acceleration.

I want to make it absolutely clear that I am not arguing that the scalar vector 'acceleration', as it is technically defined, cannot exist at an instant. But I find it highly counterintuitive to consider its existence at an instance as being independent of the existence of a temporally extended change in velocity, which is what we intuitively understand acceleration to be. As far as I can tell, Huemer and Kovitz fail to make this distinction between the technical and intuitive meaning of 'acceleration'. Their main point is to show that the second law describes "a continuous relationship existing between the variables *F* and *a* throughout any time interval: a force exerted for any length of time causes a *change in velocity* over that interval proportional to the integral of the force over the time interval" (2003: italics are mine, RI). I have no objection to the suggestion that there exist such a simultaneous relationship between the variables F and a, but I think that it isn't clear whether that relationship should be identified with the relationship between the exertion of force by A on B, and B's ensuing change in velocity. Scalar vectors arguably represent the tendency of a property (velocity) to increase or decrease over time on a given scale. The tendency can arguably exist without manifesting itself in a real change. A hand pressed on a surface has a motion vector (a direction tendency), even though it does not move as long as the surface prevents it from moving. It could also be said to have a tendency to accelerate without actually be in motion.

To repeat, the philosophical problem is the following. If the second law is to be understood as an expression of causality, it must link a cause to the effect it produces, i.e. a cause and a *change* (or result of change), and, *intuitively*, acceleration is a change in an objects velocity between two times, but this is not what ‘acceleration’ is in the technical sense. Newton himself talked about acceleration informally as ‘a change of motion’ (1687). As all changes, change of velocity is essentially temporally extended. Before the invention of the infinitesimal and integral calculus, this was indeed how acceleration was defined mathematically as well (see Johansson 2005, ch. 7.2). However, the infinitesimal and integral calculus, invented by Newton, made it possible to define the magnitude of acceleration for an infinitesimal time-point. As a result, acceleration became treated as the *rate* of that change defined for an instant, from being treated as the change from one velocity to another, which essentially takes time. This shift is apparent even in the difference in which Newton talks informally about acceleration as change of motion and how he defines it mathematically as rate-of-change-of-motion. It is then the rate-of-change-of-motion that has become the standard way to talk about acceleration in classical mechanics, as this citation from G. Buchdal shows:

> A fairly accurate translation of the Second Law of Motion as it occurs in Newton’s Principia is as follows: ‘The *change of motion* is proportional to the motive force impressed; […] In modern terminology this may be rendered: ‘*Rate of change of momentum* is proportional to the unbalanced force [...]’ (1951, p. 217).

The philosophical problem is here whether the vector quantity called ‘instantaneous acceleration’ can really be counted as the ontologically basic manifestation of the effect of the force, or whether it is only an instantaneously existing property of something undergoing temporally extended change of velocity. Like Bigelow and Pargetter (1989), and Johansson (2005, ch. 7.2), I favour the idea that the existence of a rate of change of velocity depends on the existence of a change in velocity; rate as a characteristic of change, but change not a consequence of rate. If the second law is to be treated as an expression of causality, acceleration must be an effect, and therefore involve a change. The rate of change of motion is arguably a mathematically calculated vector quantity, and can as such exist at an instant, precisely because it is not a change.

The debate concerning the intelligibility of the notion of velocities and accelerations existing at an instant has a long history, dating back to at least Zeno’s paradoxes, which I will not comment here. I have no contribution to the solution of that controversy, I just point out some details I think are missing in Huemer’s and Kovitz’ discussion. According to recent commentators, e.g. Bigelow and Pargetter (1989), vectors in general are best understood as a property of a change rather than being the change itself, and they even speculate in whether *scalar* vectors should be interpreted as a second order property of a change, i.e. the property of a property of a change. In that case ‘acceleration’, in the technical sense, would not itself manifest a change, but merely a second order property of a change at a given time.

The final point is that on the interpretation favoured by Johansson, Bigelow and Pargetter, there is a logical space for a staggered interpretation similar to that proposed by Kant (1787, sect. A203ff). It is possible to conceive of a force being exerted by object A on object B and that this produces an *ensuing* change in velocity, and nevertheless that the rate-of-change-of-velocity, i.e. acceleration, is at any given time proportional to the force being exerted. This is possible because the rate of change of velocity merely reflects a tendency to a change, which is only realised *a posteriori* of the existence of this tendency.

To sum up, the problem is that the scalar vector 'acceleration' is arguably not a change, while acceleration, as it is intuitively understood, is a change but allows for a staggered interpretation. Now, all of this does not refute Huemer's and Kovitz' point that a force exerted for any length of time causes a *change in velocity* over that interval proportional to the integral of the force over the time interval, it just shows that this point cannot be read from the second law on its own. However, I doubt whether there is any need to definitely settle this question in order to avoid the problem of action at a temporal distance, which is the subject of the next section.

5. IS THERE A PROBLEM OF ACTION AT A TEMPORAL DISTANCE?

The problem Huemer and Kovitz claim to be solving is this: how is it possible to account for causally connected processes that take place over an extended time period, under the assumptions that time and causal processes are continuous and that a cause cannot act over a temporal distance? Well, I am not convinced that the problem of action at a temporal distance has anything in particular to do with the mathematical structure of time and temporally extended processes, and therefore that there is any need to establish that causes and effects are simultaneous in order to avoid that problem. It seems to me that the problem of action at a temporal distance is based on the mistaken conception that causes act on their *effects*. This is admittedly a view many philosophers take for granted, but it is not easily reconciled with Newton's laws of motion, nor with the common sense view that causes produce their effects through the action of something on something else.

It should be made clear that the notion of action does not belong to all accounts of causation. In particular, it does not belong to views that regard causation merely as a regularity relation between temporally distinct events. Action only belongs to those views that admit that effects are produced, or brought into existence, by the exertion of some kind of influence of something on something else; that is what action supposedly *is*.

According to this kind of realist view of causality, causes bring effects into existence by exerting some kind of causal influence on something else. This presents us with a dilemma. Since the effect is first produced through the action of the cause, the effect cannot itself be what the cause acts upon. That would require the effect to exist before it was produced. Causes cannot possibly act upon their effects *and* be what produce them. Forces cannot act, or operate, on accelerations, if accelerations are assumed to be *products* of the exertion of force, i.e. the effects of force. Indeed, the second law of motion is best read as saying that the force is proportional to the acceleration it produces *in a given mass, m*. That is to say, that it really is the body, *m*, which is acted upon (influenced by the force), and caused to change its velocity. A leaden ball does not act upon the *making* of a hollow in a pillow; it acts upon the pillow, thus making a hollow. A locomotive does not act upon the *acceleration* of a railroad car, or even on the *stretching* of the coupling, it acts upon the coupling/railroad car, thus stretching/accelerating the coupling/railroad car.

It is only on the assumption that causes act on their effects that one could think that a force F acts upon the acceleration a, and that therefore the location of a, at a time later than the exertion of F, threatens to introduce action at a temporal distance. Huemer and Kovitz discuss the implications of the second law of motion for the simultaneity of causation, but overlook that classical mechanics arguably do not depict forces as acting on accelerations. To my mind, classical mechanics are best understood as depicting forces as operating between coexisting objects, not successive events. This comes out most clearly in Newton's third law of motion, $F_{1\ on\ 2} = -F_{2\ on\ 1}$. On this reading, classical mechanics describe the relation between cause and effect, then meaning action and acceleration, as a product of a more fundamental phenomenon; an interaction (stress). Of course, classical mechanics does not deny that temporally distinct events are causally related, but it does implicitly depict those relations as something that comes into being as a *result* of an interaction. Note also that it does not *substitute*, or *reduce*, what is traditionally called the causal relation, say, between the pull of a locomotive and the motion of a railroad car, with a relation of mutual action between locomotion and railroad car.[6] It just says that the causal relation between the pull of the locomotive and the motion

[6] Mario Bunge makes this mistaken assumption in (1956). On page 162 he says: "Let us agree to call interactionism, or functionalism, the view according to which causes and effects must be treated on the same footing, in a symmetrical way excluding both predominant aspects and definitely genetic, hence irreversible, connections."

of the railroad car is not ontologically basic, but is produced by a more fundamental process/relation, that of interaction between two bodies.[7]

The third law of motion has important lessons to teach. It says, firstly, that to every force exerted by object *1* (m_1) on object *2* (m_2), there is *simultaneously* an oppositely directed force; every action is accompanied by a reaction. Secondly, that this oppositely directed force is of *equal* magnitude to the force exerted by object m_1 upon object m_2. Thirdly, it says, together with the second law, that both m_1 and m_2 undergo accelerations; at the same time as the force exerted by m_1 on m_2 causes an acceleration in m_2, then m_2 exerts a force on m_1, producing an acceleration in m_1. To sum up, both objects act simultaneously on each other with equal force, and both accelerate in proportion to the force and inversely proportional to their respective mass; the interaction is completely reciprocal.

The forces, F and $–F$ respectively, causing the accelerations in the two objects m_1 and m_2, are called *action* and *reaction*, or *force* and *counterforce*, which has invited some confusion about the nature of the relationship between the two forces. It has sometimes been assumed that we are dealing with two different kinds of actions, of which the reaction/counterforce is a product of the action/force, because of the connotations that the terms ‘action’ and ‘reaction’ have in everyday language, since they are most frequently used to describe communicative interaction. Therefore, despite the reciprocal nature of the relationship between F and $–F$, as expressed in the third law, it is often assumed either that the relationship between action and reaction is that of two different kind of actions, one being the cause and the latter the effect, or somehow involve two objects taking turns at affecting each other, like when someone slaps someone else in the face and the latter slaps back. Classical mechanics does not support any such distinction between the mutual actions involved, nor the idea of interaction involving turn taking. Indeed, the distinction between action and reaction is taken to reflect merely the subjective aspect under which an observer studies the phenomenon of reciprocal action.

If we are interested in what happens to a pillow when a leaden ball is dropped on it, the exertion of force by the ball is called an action, while the exertion of force by the pillow is called a reaction. If we are interested in what happens to a leaden ball when it falls upon a pillow, the exertion of force by the pillow is called an action, while the exertion of force by the ball is called a reaction. In the words of Hertz, “we are free to consider either of them as the force or counterforce” (1955, p. 185), and in the words of

[7] See Ingthorsson (2002) for a detailed account of how to conceive of the traditional causal relation as produced by an interaction between bodies.

James Clerk Maxwell, “The mutual action between two portions of matter receives different names according to the aspect under which it is studied” (1956, pp. 26-27). The interaction is composed of mutual actions occurring simultaneously between coexisting things. In the words of Mario Bunge, “physical action and reaction are, then, two aspects of a single phenomenon of reciprocal action” (1956, p. 153). I draw the conclusion that causation, within the conditions in which classical mechanics is known to hold good and for the objects relevant for that science, is not a matter of one object acting on an effect of the action, nor of one object acting on another object, but of two or more objects acting reciprocally on each other, producing a change in each other. If anyone would doubt that the pillow exerts influence on the leaden ball, then consider that the pillow causes the leaden ball to decelerate to a halt. Classical mechanics subsumes all changes in velocity, whether increases or decreases, under the term ‘acceleration’.

Bigelow, Ellis and Pargetter, in ‘Forces’ (1988), discuss the idea that objects are the *relata* of actions, and hence of forces. According to them, talk of forces as operating between objects is a legitimate but derivative mode of expression. Since forces clearly operate between a cause and an effect, they argue, they *must* primarily relate events or states, even though the existence of those events and states is dependent on the things to which those events happen and whose states they are. However, as far as I can see, their assumption that forces must operate between events or states, rests entirely on the fact that in contemporary philosophy causal relations are assumed to hold, *as if by definition*, between events or states. And, because they consider forces to be a special kind of causal relation, it must relate events or states. However, the subject of this discussion is the question of how we should conceive of the nature of causal influence in the mind-independent reality, and as far I know, we do not have the power to determine by stipulation what its nature is. We can only make conjectures about its nature, and may well have to reconsider deeply entrenched intuitions about causality in the light of new insights. The idea that causes act on their effects is, I suggest, due for reconsideration in light of classical mechanics.

To repeat, my reason for thinking that forces cannot operate between events, or, that events cannot act on the events they themselves produce, is that actions are conceived of as an influence of something on something else, *and* as something which produces an effect. It is impossible to puzzle these two ideas together with just two events and the assumption that the former acts upon the latter. It is impossible that an event could produce another event by acting on it, because that would require the former event to act upon something which has not yet been produced, and by so doing bring into existence the very event it is acting on. The only kind of entity that can possibly be the *relata* of actions (interactions) are two independently given and coexistent objects.

Note again that this account by no means reduces causality to the reciprocality of action and reaction, it just explains the nature of causes in a somewhat different manner than usual. The causal relation still holds between the cause (interaction) and the ensuing effect (acceleration of interacting objects).

6. CONCLUSION

I have argued, firstly, that Huemer and Kovitz do not adequately take into consideration the difference between the ordinary connotation of the term 'action' and what the time derivate 'rate-of-change-of-velocity' stands for as it is technically defined. Therefore they miss entirely ontological problems relevant for their claim that Newton's second law of motion illustrates the true simultaneous nature of the relationship between causes and effects. Secondly, I have argued that the very problem they set out to solve is based on an idea about action that is not easily reconciled with classical mechanics. They assume that forces act or operate on accelerations, while Newton's third law of motion is surely best read as stating that objects act reciprocally on each other, thus producing accelerations. On the reading I advocate it isn't obvious that there is any problem of action at a temporal distance as long as the interacting bodies exist simultaneously. There is still a general problem concerning contiguity between distinct objects in a spatial continuum (see e.g. Smith & Varzi 2000), which is of course relevant for the question of causal influence in accordance with the principle of locality, but I am not convinced that there is a comparable temporal aspect to that problem.

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