Processes, Pre-emption and Further Problems[1]

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In this paper I will argue that what makes our ordinary judgements about token causation ('actual causation') true can be explicated in terms of interferences into quasi-inertial processes. These interferences and quasi-inertial processes can in turn be fully explicated in scientific terms. In this sense the account presented here is reductive.
I will furthermore argue that this version of a process-theory of causation can deal with the traditional problems that process theories have to face, such as the problem of misconnection and the problem of disconnection (Dowe 2009) as well as with a problem concerning the mis-classification of pre-emption cases (Paul and Hall 2013).

1 Introduction

In the last two decades much interesting work on causation was work on causal graph theories (Pearl 2000, Spirtes et al. 2000, Woodward 2003, Halpern & Pearl 2005, Schurz & Gebharter 2016). At least some of these authors explicitly distinguish between causal graphs on the one hand and the causal building blocks they represent on the other (e.g. Pearl 2000, xiii-xiv). What I will present here is an account of such building blocks or – as Mackie put it – of causation "in the objects" (Mackie 1980, ix). Such an account may even increase the content of causal graph theories by adding constraints that are motivated by the nature of the mechanisms underlying the causal models (Schurz & Gebharter 2016, 1096), i.e. by the nature of causation 'in the objects'. Spelling out these connections in more detail will, however, not be part of this paper – though I will briefly return to this issue in section 7.
The main aim of this paper is to explore what we usually refer to by "causation" (in the sense of 'token causation' or 'actual causation') and how this fits into a world as described by the sciences. As I will argue a process-theoretic account in terms of quasi-inertial processes is the most promising candidate. In this paper I will deal with the most important challenges that process-theories have to face, i.e. the problem of misconnection, the problem of disconnection

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(Dowe 2009) and a problem concerning the mis-classification of pre-emption cases (Paul and Hall 2013).

In what follows I will argue that our ordinary concept of token causation can best be understood in terms of quasi-inertial processes and interferences (this is what I call the 'disruptive' concept of causation). There are, however, other uses of the term 'cause' – for example when applied in some physics contexts. In section 2 I will briefly sketch what I call 'closed system causation'. The analysis of the 'disruptive' concept of causation comprises two steps. First I will analyse causation in terms of quasi-inertial processes and interferences (section 3). Next I will argue that quasi-inertial processes and interferences can be understood in scientific terms (section 4). From section 5 onwards, I will show how this concept of causation tracks our causal intuitions in pre-emption cases and how the traditional problems process theories are confronted with can be dealt with. Finally in section 7 I will briefly relate my account of token causation to other approaches.

2 Caveat

While I will argue that most of our 'ordinary' causal judgements are true in virtue of underlying quasi-inertial processes that are interfered with, this does not seem to be true of all our causal judgements.

The physicist Peter Havas observed:

> "We are all familiar with the everyday usage of the words 'cause' and 'effect'; it frequently implies the interference by an outside agent (whether human or not), the 'cause', with a system, which then experiences the 'effect' of this interference. When we talk of the principle of causality in physics, however, we usually do not think of specific cause-effect relations or of deliberate intervention in a system but in terms of theories, which allow (at least in principle) the calculation of the future state of the system under consideration from data specified at time t_0." (Havas 1974, 24)

Havas points to what might be called 'closed system causation': One state of a (closed) system causes another state of the same system to obtain provided the former (uniquely) determines the latter (by virtue of the laws of nature). When we consider a chair being in a particular place and time to be the cause of its being there five minutes later, we are dealing with a simple case of closed system causation.

The most important difference between closed system causation and our ordinary conception is highlighted by the fact that causation in terms of interferences into quasi-inertial processes disrupts exactly what closed system causation presupposes: that the system in question is closed (see Scheibe 2006, 223).[2]

Closed system causation does not provide a problem for an attempt to give a reductive account of causation in terms of scientific facts. However, it does not fall under the concept of causation that I propose in the remainder of the paper.

In what follows I will focus on causation in terms of interferences. As I will show below it is this concept of causation that tracks our causal intuitions in pre-emption scenarios (and elsewhere).

3 The Disruptive Concept of Causation: First Step of an Analysis

Mach observed at the beginning of the last century that "[i]n general we only feel the need to ask for a cause, if a (unexpected) change has occurred" (Mach 1986, 432; for similar observations see Kahneman and Miller 1986, 148; Hitchcock and Knobe 2009). While this remark expresses a psychological observation, Hart and Honoré have similarly analysed what they take to be our ordinary common-sense concept of causation. They observe that

> "[c]ommon experience teaches us that, left to themselves, the things we manipulate, since they have a 'nature' or characteristic way of behaving, would persist in states or exhibit changes different from those which we have learnt to bring about in them by our manipulation."

They then go on and state:

> "The notion, that a cause is essentially something which interferes with or intervenes in the course of events which would normally take place, is central to the common-sense concept of cause" (Hart and Honoré 1959, 27).[3]

These psychological and semantic observations suggest an account of causation according to which what we pick out by the word "cause" is an interference with a quasi-inertial process. In what follows I will sketch such an account.

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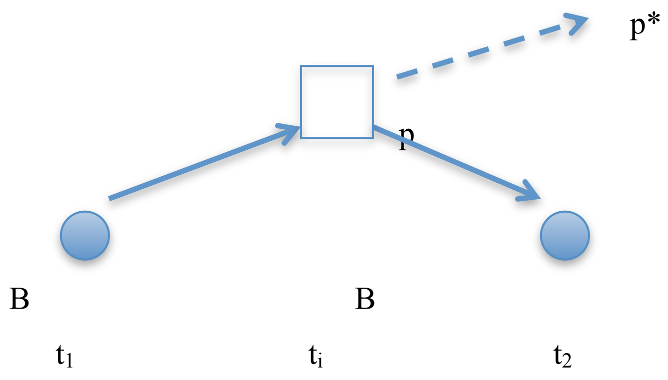
[2] The behaviour a system would undergo if it were closed (i.e. if it would not interact with other systems) is an example of what I will call "quasi-inertial behaviour" (see section 4).

[3] In contrast to Hart and Honoré, I will not discuss quasi-inertial behaviour in terms of "normality," but rather in terms of quasi-inertial behaviour, which might be taken to be a different way of spelling out a system's "characteristic way of behaving".

Let me introduce the central idea by way of a simple and idealized example (Fig. 1): Two billiard balls, A and B, bounce against each other at t_i and are deflected. We take the presence of ball A at a particular place at t_i as the (actual) cause for B's deflection. Why is this so



p: B's actual path

p*: the path B would have taken if A had not interfered at time t_i

Fig. 1

What makes our causal judgment correct? According to Newton's first law, B will display a certain inertial behaviour, namely, to simply continue in a straight line with uniform motion (path p*), provided there are no interfering factors. Newton's first law describes the (quasi-)inertial behaviour of B. (I take *quasi-inertial behaviour* to be a generalisation of *inertial behaviour* that refers to the temporally extended behaviour of systems that are not interfered with (see section 5.1 for details). However, this quasi-inertial behaviour of B is not displayed; B takes path p rather than path p*. If the quasi-inertial behaviour does not occur, Newton's first law tells us that there must be some factor that interacted with B (the box in Fig. 1 represents the interaction). The event of A interacting with B is the cause of the quasi-inertial behaviour not being displayed. More generally, the cause is something that interacts with or disturbs the system under consideration, such that instead of the latter's quasi-inertial behaviour, another behaviour occurs.

More precisely and translated into event talk, this can be stated as follows ('DC' stands for the definition of the disruptive concept of causation):

> Let Z_i (t_2) be the state that a system S (at an earlier time t_1) is disposed to be in – provided nothing interferes between t_1 and t_2. Let e be the event of S being in state $Z_e(t_2)$ at t_2, where $Z_e(t_2) \neq Z_i(t_2)$.

(DC) An event *c* is a cause$_{DC}$ of an event *e* iff *c* is the event of some factor interfering with the quasi-inertial behaviour of system S between t_1 and t_2 such that S at t_2 is in state Z_e, rather than in state Z_i.[4]

(DC) gives us a contrastive notion of causation because the cause is a cause for S being in state Z_e *rather than in state* Z_i. (DC) is contrastive with respect to the effect (cf. Schaffer 2005 who advocates contrastivity with respect to causes as well. (DC) can easily be made contrastive with respect to causes as well if the occurrence of c is contrasted with the absence of c.)

Clearly, there are a number of terms in (DC) that need to be explicated; 'quasi inertial behaviour' and 'interfering factor' will be treated in section 4; the phrase 'such that', which will lead to a distinction between relevant and irrelevant interferences, will be dealt with in section 5.

Let me, however, start with another illustration of what is involved in a causal claim according to this first step of analysis. In this account we should analyse a claim like 'The striking of the stone causes the shattering of the window at t' as being true in virtue of the following:

(1) An event *e* (the effect) obtains: System S (the window) is in state Z_e at t (it is shattered).
(2) The quasi-inertial behaviour of S would have led to S being intact at t (S in state Z_i, which is different from Z_e): In the absence of interfering factors the window, which as a matter of fact is broken would have remained intact.
(3) An event c obtains (the stone hits the window), which is an interference with the quasi-inertial process such that S at t is in state Z_e rather than Z_i.

What is essential for the determination of the quasi-inertial behaviour or quasi-inertial process – as will become clear in the discussion below – is that we start with the effect in question. According to the account presented here, the effect consists of a system S being in a state Z_e at a certain time t that is different from or deviant relative to the quasi-inertial behaviour of

[4] As indicated at the outset, my aim in this and the following sections is not to cover all uses of the word 'cause', but rather what I have called the 'disruptive' concept of cause. So close-system-causation (and that includes "standing factors", which I take to be causes in virtue of being part of the state of a closed system) will not fall under the disruptive concept of causation. So what I am providing here are necessary and sufficient conditions for this particular concept. In the remainder of the paper I will skip the subscript "DC".

the system at that time. When looking for a cause we are looking for something that brought about this deviation.

4 The Disruptive Concept of Causation: Second Step of an Analysis

The second step of the analysis of the disruptive concept of causation consists in showing that the crucial notions in the characterisation of actual causation ("quasi-inertial process" and "interfering factor") can be understood in scientific terms. What is essential for the account to work is not that all quasi-inertial processes have a common physical feature, but rather (1) that in every single case of actual causation there is a determinate and objective fact of what the quasi-inertial process of the relevant system is and (2) that in every single case the quasi-inertial behaviour can be characterised in scientific terms, so as to ensure that causal facts are nothing above and beyond those facts which can be characterised by the various scientific disciplines.

4.1 Quasi-inertial processes

Central for my account of causation is the notion of a *quasi-inertial process*. In physics, the *inertial motion* of a massive particle is defined as the motion of a free particle, i.e., a particle free from external forces acting on it. My notion of *quasi-inertial process* or *quasi-inertial behaviour* generalises this aspect of inertial motions: it refers to the temporally extended behaviour of systems that are not interfered with. A few examples should provide us with a better grip on this notion.

Example 1: Newton's first law describes the (quasi-)inertial behaviour of a massive particle: "Every body continues in its state of rest or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it" (Newton 1999, 416). The law describes the systems in question ("every body") that are disposed to display a certain behaviour ("continues in its state of rest or of uniform motion in a straight line") provided there are no interfering factors ("unless it is compelled to change that state by forces impressed upon it").

Example 2: Galileo's law of free fall defines a quasi-inertial process: A free falling object in a vacuum displays a certain behaviour, as long as the falling object is free, i.e., as long as no interfering factors intervene.

Example 3: The Lotka-Volterra equations describe the temporal development of a biological system consisting of two populations of different species: one predator, one prey. The relevant equations for prey–predator populations are (1) $dx/dt = x (a – by)$ and (2) $dy/dt = - y$

(c – gx), where *x* represents the number of prey and *y* the number of predators of some kind, and *a*, *b*, *c*, and *g* are constants. These equations describe a quasi-inertial behaviour in that they describe the behaviour that a biological system is disposed to display provided there are no interfering factors (e.g., additional predators or severe floods).

Example 4: According to the economic law of demand, provided all else is equal, as the price of a good increases, quantity demanded decreases; conversely, as the price of a good decreases, quantity demanded increases. Thus, certain kinds of systems (economies) are disposed to display a certain temporal development provided there are no interfering factors (e.g., state interventions that fix prices).

A number of points should be noted. First, whether a certain kind of system is disposed to display some kind of quasi-inertial behaviour is an objective matter for which the usual sorts of scientific evidence are available. Some claims about quasi-inertial processes can be (more or less directly) empirically tested (e.g., Galileo's law of free fall or the Lotka-Volterra equations), while in other cases, empirical and theoretical considerations together provide warrant for our acceptance of the laws, equations, and so on, that represent attributions of quasi-inertial processes, for instance in the case of the law of supply and demand. What counts as a quasi-inertial process and a deviation therefrom may also be constrained by very general theoretical considerations, such as those that led people to give up an Aristotelian conception of the natural world and adopt a Newtonian one (and with it different conceptions of quasi-inertial behaviour) instead. The essential point is that we have the usual scientific evidence for characterising quasi-inertial processes. Physics tells us that free falling objects fall (roughly) according to $s = ½ gt^2$; that is the quasi-inertial process for such objects. It is *false* that free falling objects fall (roughly) according to $s = ½ gt^4$. Similarly for other disciplines or branches of science; for example, biology tells us that the relevant equations for prey–predator populations are (1) $dx/dt = x (a – by)$ and (2) $dy/dt = - y (c – gx)$, and according to the evidence we have, the equations (1*) $dx/dt = x^2 (a – by)$ and (2*) $dy/dt = - y^2 (c – gx)$ provide *false* descriptions of the temporal evolution of such populations.

Second, the quasi-inertial processes we are looking at might be internally quite complex. Within the quasi-inertial temporal development as described by the Lotka-Volterra equations, there might be all kinds of other processes taking place (e.g., rabbits eating grass or playing). These processes might themselves be quasi-inertial processes of systems that are part of the biological system described by the Lotka-Volterra equations.

Third, the notion of a quasi-inertial process is closely connected to that of an *exclusive* ceteris paribus law. Exclusive ceteris paribus laws describe a relation between properties of a system or the behaviour of a system that obtains *provided certain factors are absent*. All four cases mentioned here are examples of exclusive ceteris paribus laws. (Examples 3 and 4 are mixed in the sense that they are also comparative ceteris paribus laws, where *comparative* ceteris paribus laws assume that *factors not explicitly mentioned remain constant*; see Schurz 2002 for this classification of ceteris paribus laws).

Fourth, even though I have introduced quasi-inertial processes via *ceteris paribus* laws so as to make clear that such processes can be fully accounted for by the sciences, I do not claim that there is an explicit *ceteris paribus* law for every quasi-inertial process. On the contrary: Consider again the example of a falling stone. Galileo's law – a *ceteris paribus* law – describes one particular quasi-inertial process, namely free fall. There are however, many other quasi-inertial processes in the vicinity, e.g. a falling stone in air, in water or other media, even though we do not have explicit *ceteris paribus* laws for the behaviour of these systems. This is an important point for otherwise one might be tempted to think that the analysis of disruptive causation only works for the idealized cases described in explicit *ceteris paribus* laws.

Finally and most importantly the identification of quasi-inertial processes is relative to a prior identification or specification of the systems. This introduces a certain pragmatic or perspectival element into the account presented. I might, for instance, be interested in *falling objects in a vacuum*. Once this has been settled, it is—as mentioned above—an objective matter what the quasi-inertial behaviour is. Once we have identified the system we are interested in, e.g. the falling stone in water, and once the initial conditions are fixed, there is only one kind of behaviour this system will display provided there are no interfering factors. In other circumstances, however, I might be interested in the behaviour of *falling objects in a medium*; then the system's quasi-inertial behaviour will be different. But that is not surprising, given that we are looking at different systems. Similarly, we might want to examine the quasi-inertial temporal development of a system consisting of prey and predator populations, say, foxes and rabbits (in a certain environment). The behaviour of such a system can be described by the Lotka-Volterra equations. However, there might be another situation in which we simply want to know the quasi-inertial temporal development of the population of rabbits (in a given environment) and treat the foxes as interfering facctors. Biology does not tell us what kind of system we should study; instead, it gives us information about the quasi-inertial behaviour of the systems that we have chosen.

This point helps to address a worry that has been raised by Blanchard and Schaffer. In the context of constructing causal models with default values they observe that

> “default status seems conflictingly overdetermined in many cases. Suppose […] that Sally (like most other drivers on the road with her) is driving 65 mph in a 55 mph zone, and gets into an accident that would not have occurred had Sally been driving at 55 mph. […] But how are we supposed to assign default or deviant values to [the variable] Speed? The social norm is to drive 55 mph, but the statistical norm is to drive 65 mph.” (Blanchard & Schaffer 2017, 194)

What I call ‘quasi-inertial’ behaviour is relevantly different in two respects from the notion of ‘default’ behaviour considered by Schaffer and Blanchard. First, they consider systems (drivers) with different options (55mph, 65 mph etc.). By contrast the quasi-inertial behaviour of systems we were discussing is completely determined once the initial conditions were fixed. So in the case of Sally, either the system is deterministic but we do not know the initial conditions of the system and thus even though it is determined we simply don’t know what the quasi-inertial behaviour is; or the system is indeterministic and thus falling outside the scope of quasi-inertial behaviour considered in this paper (see Hüttemann 2013 for dealing with indeterministic quasi-inertial processes). Second, for Schaffer and Blanchard it is *external* considerations (relative to the system, i.e. relative to a single driver such as Sally) that determine whether one of these options, i.e. one of these behaviours can be classified as ‘default’ (social norms, statistics). Neither point applies to the quasi-inertial behaviour I have discussed. There is exactly one way in which the free falling stone can fall in vacuum. Its quasi-inertial behaviour is due to intrinsic features of the system and completely independent of system-external social norms or statistical considerations.

So far I have argued that Schaffer and Blanchard’s considerations do not apply to falling stones and other systems I have discussed above. But what about Sally? What is her quasi-inertial behaviour when sitting in a car on the highway? Let me start by discussing a slightly less complex case.

Take the rabbit: Is its quasi-inertial behaviour to continue to live or to die? This is an ambiguous case. Note, however, that the ambiguity is entirely due to the fact that the question does not uniquely specify what the relevant system is. If we are considering the rabbit completely on its own, i.e. in a world without oxygen, grass etc., its quasi-inertial behaviour presumably is to die pretty soon. If on the other hand the question is meant to refer to a rabbit in a different context, i.e. to a different system, the answer may very well be different as well. In other words: The quasi-inertial behaviour of the system in question depends on features of the system and the question for the quasi-inertial behaviour of “the rabbit” is too vague to allow for a unique answer. The same reasoning applies to Sally. Absent further specifications of the system *Sally on the highway*, the best we can get at empirically will presumably be probability distribution over different speeds. It is only if we add details to the system, e.g. whether and under what circumstances Sally complies with the social norm, that we will get a definite quasi-inertial behaviour.

Given the multiplicity of systems we might individuate and the corresponding multiplicity of quasi-inertial processes one might wonder about the implications for causal explanation. In a causal explanation we typically (though not always) attribute *a* cause rather than a multiplicity of causes. What is the mechanism that slashes the multitude of quasi-inertial processes? The essential point is that in a causal explanation we start with the specification of an effect. Something has happened, often something unexpected. In a causal explanation what has happened is contrasted with another course of events, another process, that would have led to the non-occurrence of the effect. By this procedure the first two conditions for causation discussed in section 3 (as applying to a window that is shattered by a stone) are specified:

(1) An event *e* (the effect) obtains: System S (the window) is in state Z_e at t (it is shattered).
(2) The quasi-inertial behaviour of S would have led to S being intact at t (S in state Z_i, which is different from Z_e): In the absence of interfering factors the window, which as a matter of fact is broken would have remained intact.

Thus it is by *specifying the effect* that the multitude of possible systems/inertial processes (in this case: (i) the window pane remaining intact and (ii) the window pane & the stone developing into a shattered window and a stone lying around somewhere) is reduced (in this case to: the window pane remaining intact). In other words, a perspectival or pragmatic element is part of the account presented here because the effect to be accounted for can be specified in different ways (a noise (rather than no noise), a loud noise (rather than a gentle noise), a noise that occurred in the morning (rather than a noise that occurred in the afternoon)). However, once the effect is specified it is an objective matter which quasi-inertial process needs to be considered.

Thus, even though in our ordinary practice of causal explanation these specifications are fairly vague the important point is that the specification of the effect fixes the relevant quasi-inertial behaviour (as well as the system involved).

4.2 Interferences

What goes for quasi-inertial processes goes for disturbing or interfering factors as well. The case of Newtonian physics is particularly simple: The first law not only explicitly specifies a system's (quasi-)inertial behaviour; it furthermore states what the possible interfering factors are ('impressed forces'). Moreover, the second law describes the exact influences of these interfering factors (it is a 'law of deviation'; Maudlin 2004, 431). Newton's laws thus give us two kinds of information that allow us to characterise what the relevant interfering factors are: First, they tell us what candidate interfering factors there are ('impressed forces'), and second, they tell us exactly how these factors, if interacting, modify the quasi-inertial behaviour.

In other disciplines, there are no general and explicit accounts of interfering factors, but it seems plausible to argue that there is implicit knowledge concerning what counts as a legitimate interfering factor and how such a factor might qualitatively modify the envisaged quasi-inertial behaviour. In economics, for example, state interventions or the decisions of the federal reserve bank might be considered as candidates for interfering factors, and we also know (or at least form hypotheses about) how, for instance, the change of certain interest rates modifies what can be considered the quasi-inertial behaviour of an economic system. Both quasi-inertial processes and interfering factors are identified in the sciences on a case-by-case basis.

What this account provides is thus a rather *thin* concept of actual causation: A description of what happens in terms of 'cause' and 'effect' is abstract and coarse-grained. A more fine-grained description will turn to the details that are provided by the underlying physics, biology, or economics. However, there is something that these cases of token causation have in common and in virtue of which causal claims are true: First, there is a system that is disposed to a specific quasi-inertial behaviour, and second, the quasi-inertial process is not displayed, due to an interfering factor.

4.3 Worries

Let me mention some worries. First, isn't the account circular in the sense that it spells out causal terminology in terms of quasi-inertial processes and interfering factors, which in turn are causally laden terms? Another way of putting this worry is: Doesn't the account fail to be reductive? My response is that the account presented here *is* a reductive account, at least in one sense of 'reduction'. Accounts of causation can be reductive in various ways. First, one might attempt to define or explicate the concept of causation without relying on causal terminology ("semantic reductionism"). Second, one might try to provide an account of how causal claims are tested without relying on prior knowledge of (other) causes ("epistemological reductionism"). I do not claim that the account presented here is reductive in either the semantic or the epistemological sense. Third, however, one might try to give a reductive ontological account of causation. This last one comes in (at least) two varieties. The first attempts to reduce causal facts to noncausal facts, while the second attempts to reduce causal facts to facts described by underlying sciences. These two versions of ontological reduction may not coincide: if basic physical assumptions of fundamental physics turn out to be causal assumptions, as Frisch argues (Frisch 2014), a reduction to physical facts would not amount to a reduction to noncausal facts. My focus is not the reduction of causal facts to noncausal facts, but rather the reduction of macroscopic causal relations to facts described by the underlying sciences such as physics or biology (whether causal or not). It should also note that a pragmatic or perspectival element comes into play via the specification of the effect. So the reductive project is not overly ambitious: the claim is that once the effect is specified, the causal facts that account for the effect can be characterised in terms of the underlying sciences.

The distinction of different projects may give rise to a second worry. Dowe made a twofold distinction between a conceptual analysis of causation on the one hand and an empirical analysis on the other. The conceptual analysis of causal concepts aims to explicate the concepts through an appeal to causal intuitions, while an empirical analysis "seeks to establish what causation in fact *is* in the actual world" (Dowe 2000, 3). Given that my ontological project falls into the latter category one might wonder whether my reliance on causal intuitions and causal judgements of ordinary, competent English speakers might be misplaced. While I generally share the scepticism regarding the relevance of conceptual analyses for metaphysical claims, I take the situation to be different in the case of causal concepts. Causal reasoning, causal beliefs and causal concepts are deeply engrained in our cognition and may be arguably at least in part neurologically hard-wired (see Danks 2009 for an overview). From an evolutionary perspective it makes sense to assume that our causal intuitions by and large carve nature at its joints. Thus, in the special case of causal intuitions we have good reasons to consider these intuitions as evidence for features of the actual world. And my aim is to show that our causal intuitions can be reconstructed as intuitions about quasi-inertial behaviour and interfering factors.

5 Pre-emption

So far, I have elaborated a suggestion concerning which scientific facts we pick out when we use causal terminology in ordinary contexts, namely, facts about interfering factors with quasi-inertial processes. In what follows, I will argue that such a concept of cause accounts for at least the causal intuitions we have in pre-emption scenarios.

Consider the case of late pre-emption. Suzy and Billy both throw stones at a window; Suzy's stone gets there first and shatters the window. Billy's stone arrives at the scene a bit later but does not destroy the window because the latter is already shattered.

As is well known (Lewis 1986; Collins, Hall and Paul 2004, 22–23), late pre-emption is a problem for (simple) counterfactual accounts of causation: It is not true that if Suzy had not thrown the stone, the window would have remained intact.

If the account in terms of quasi-inertial processes and interfering factors is correct, we have an explanation of our intuitions in the case of late pre-emption: The effect in question is the shattering of the windowpane at t (The windowpane is our system S, Z_e is its state of being shattered). According to our definition, when we consider an event *c* to be a cause of another event *e*, we assume that *c* is the event of some factor interfering with a system S such that S develops into a state Z_e at t, rather than some state Z_i at t into which S would have developed if the quasi-inertial process had been displayed. The effect we want to account for is the windowpane being shattered rather than non-shattered. Thus the windowpane sitting in its frame and remaining intact is the system's quasi-inertial behaviour in question. Without an interference the quasi-inertial process would have resulted in the window not being shattered at t (state Z_i). As a matter of fact, the windowpane's quasi-inertial behaviour has been interfered with by Suzy's stone, such that the quasi-inertial behaviour has not been displayed. Thus, according to our account it was Suzy's stone that caused the shattering of the window.[5]

By contrast the windowpane's quasi-inertial behaviour has not been interfered with by Billy's stone such that the quasi-inertial behaviour has not been displayed. There was e.g. no energy transfer from Billy's stone to the windowpane because the windowpane was all already shattered when Billy's stone arrived. So Billy's stone did not cause the shattering of the window.

[5] Strictly speaking the stone hitting the pane is the cause of the shattering. Suzy throwing the stone is the cause of the shattering only we allow it to be the case that if c causes d and d causes e that c is a cause of e (maybe provided further conditions obtain – the issue of the transitivity of causation is dealt with in an extended version of this paper).

The account just outlined is what one would expect from a process theoretical perspective on causation. Causation does not consist in counterfactual dependence but rather in the fact that a process of a certain specified kind has been interfered with. However, there are problems with the process theoretical solution to the pre-emption problem. The main point is that relevant interferences have to be distinguished from irrelevant interferences. This has been dubbed the "problem of misconnection" (Dowe 2009, 221). Let me approach this issue by discussing a number of objections to the foregoing solution of the pre-emption problem.

Objections

First, the case is pretty straightforward as long as we assume gravity to be switched off. However, if we switch on gravity we can ask: What about Billy's stone—didn't it interfere with the windowpane too, by virtue of a gravitational interaction? Clearly the *manner* in which the window shattered would have been different had Billy's stone not been present at all. Thus we should count Billy's throwing of the stone as an interfering factor – rather than a cause and a preempted cause we would have two contributing causes (for a discussion see Paul and Hall 2013, 56-57). But that would not capture our intuitions in this case, according to which Suzy's throwing of a stone is the only cause.

By way of rejoining let me start by specifying what the process theorist is committed to. A process theorist argues that causation is a matter of interference with certain kinds of processes (in my case: quasi-inertial processes). If there are various interferences the question is whether these interferences were relevant for bringing about the effect. Thus, in order to account for our intuitions in the modified pre-emption case it does not suffice to merely identify the interferences we furthermore have to make a distinction between those interferences that are relevant and those that are not. (Those that are relevant are interferences *such that* the effect occurs; see definition (DC) in section 3.) Being an interference is thus not sufficient for being a cause. A cause is a *relevant* interference.

So why is the gravitational interaction of Billy's stone not relevant for the shattering of the window? An essential point is that when we want to specify a cause of a certain event, we first have to specify the effect for which we seek the cause. Remember that our notion of disruptive causation is contrastive with respect to the effect. It makes a difference whether we are looking for the cause of there being a noise (rather than no noise) or whether we are asking for the cause of there being a loud noise (rather than a moderate noise). Depending on how we specify the effect, we need to consider different systems/quasi-inertial processes and different interfering factors. So if the effect is the shattering of the window (in contrast to its remaining intact), Suzy's stone striking the window will be the *relevant* interacting factor. The gravitational interaction that has also taken place between Billy's stone and the windowpane is too small to cause the window to shatter. We know this in virtue of physical laws of interaction, conservation of energy, etc. If there had only been the gravitational interaction with Billy's stone, the window would have remained intact. Conversely, if there had only been Suzy's throw, the shattering would have occurred anyway. Only Suzy's stone interacts with the system S (the window) *such that* S at t is in state Z_e, rather than in state Z_i and thus qualifies as an interfering factor for the effect in question. I suggest therefore that there is a counterfactual test that allows us to isolate the *relevant* interacting or interfering factors. The relevant interacting factors are those that interact *such that* the effect occurs.

Second, I used counterfactuals to help identify which throwing interferes with the quasi-inertial process such that the effect is brought about. But what counterfactuals are we to consider, and why are we to consider those specific counterfactuals as opposed to some others? The following counterfactuals seem plausibly relevant to the case at hand: (a) if Suzy had not thrown her stone *in the absence of Billy's stone*, then the shattering of the window would not have occurred and (b) if Billy had not thrown his *in the absence of Suzy's stone*, then shattering of the window would not have occurred. Both (a) and (b) are true. Why are these counterfactuals not the ones relevant to determining which event interferes with the quasi-inertial process of the window remaining intact?

The answer is that the counterfactual test has a particular purpose. The purpose of the test is to find out which of the various *actual* interferences bring about the effect, i.e. which interferences are those that are relevant for the occurrence of the effect (given all the other interferences) and which are irrelevant for the occurrence of the effect (given all the other interferences). So the recipe for determining whether an interference is relevant for a particular cause (or *such that* the effect occurs) consists in considering the following counterfactual: In the antecedent we consider a situation in which all the interferences are as they are in the actual situation with the exception of the inference with respect to which we try to figure out whether it is relevant. The interference whose relevance we consider needs to be eliminated. If despite the elimination the effect occurs the interference is irrelevant. If, given the elimination, the effect fails to obtain, the interference in question is relevant.

Thus the following counterfactuals need to be considered to determine whether a particular interference into a quasi-inertial process was relevant for the shattering of the window:

(A) ‘If Suzy had not thrown the stone (and thus the interference in terms of momentum and energy transfer from Suzy’s stone had not taken place), the window would not have been shattered, provided (i) all the other interferences/interactions (except those interferences that occur as a consequence of the interaction under consideration, i.e. Suzy’s throw)[6] are held fixed – and that includes in particular that Billy’s stone interacts with the window only via gravitation and not via momentum or energy transfer and (ii) no new interferences have been added.’

This counterfactual comes out as true, therefore the throwing of the stone by Suzy (or rather the interference of the stone in terms of momentum and energy transfer) is a relevant interference for the shattering of the window.

(B) ‘If Billy had not thrown the stone (and thus the interference in terms of gravity had not taken place or had been weaker), the window would not have been shattered, provided (i) all the other interferences/interactions (except those interferences that occur as a consequence of the interaction under consideration, i.e. the gravity due to Billy’s throw) are held fixed – and that includes in particular that Suzy’s stone interacts with the window only via momentum or energy transfer and (ii) no new interferences have been added.’

This counterfactual comes out as false, therefore the throwing of the stone by Billy (or rather the interference of the stone in terms of gravity) is an irrelevant interference for the shattering of the window.

For the purpose of distinguishing relevant from irrelevant interferences among those interferences which actually occur the counterfactuals to consider are (A) and (B), not (a) and (b).

To sum up the considerations concerning relevance:

An interference into a quasi-inertial process is *relevant* with respect to an effect e (it is an interference *such that* the effect e occurs) iff had the interference not occurred, the effect

[6] Why is there this exception-clause? As I indicated above (fn. 5) Suzy’s throw is not the immediate cause of the shattering. This gives rise to the following consideration: We have at least two interferences: (i) Suzy with the stone, and (ii) the stone with the window. Then, however, it is not true that "If Suzy had not thrown the stone (and thus the interference in terms of momentum and energy transfer from Suzy’s stone had not taken place), the window would not have been shattered, provided all the other interferences are held fixed". For, holding the other interferences fixed (other than Suzy's transference of momentum) implies holding fixed that the stone interferes with the window. So, the window still breaks. The clause in the bracket helps to avoid this problem. (Thanks to an anonymous referee for raising this point.)

would not have occurred either – provided (i) all the other interferences (except those interferences that occur as a consequence of the interaction under consideration) are held fixed and (ii) no new interferences have been added.[7]

Third, counterfactual reasoning plays an important role when it comes to the question of whether an interacting factor is a relevant interfering factor for a certain effect. Does this turn our analysis into a counterfactual account of actual causation? It does not. The counterfactuals hold by virtue of facts about the quasi-inertial behaviour and the deviations that are described by scientific generalisations (e.g., by exclusive ceteris paribus laws and laws of deviation). The counterfactuals typically indicate what the underlying causal structure is. Thus, we rely on counterfactuals to distinguish relevant from irrelevant interfering factors. But it is by virtue of an interference with a quasi-inertial process, not by virtue of counterfactual dependence, that Suzy's throw is classified as the cause of the shattering—as is illustrated very clearly by the hypothetical pre-emption case in which gravity is switched off.

Fourth, according to my account the throwing of Billy's stone is not relevant to whether or not the window shatters but it is relevant to the manner of its shattering. The important point is that it depends on the exact effect for which we seek a cause whether my account treats this case as a case of pre-emption or of contributing causes. And that is perfectly fine. It is thus not true that cases that we intuitively classify as cases of pre-emption have to be classified as cases of contributing causes on my account.

What I suggest here is that the shattering of the window and the particular manner of the shattering are related but numerically different events (or maybe 'aspects' or 'features' of events). One might object that if this kind of proliferation events is admissible, then there is simply no need to appeal to 'quasi-inertial process' and 'interfering factors' to explain our judgments in the case of late pre-emption; a simple counterfactual theory of causation will suffice. If Suzy had not thrown her stone, the window would not have shattered in the exact

[7] My criterion for "relevance" which I introduced to solve a problem that traditional process-theories face, namely the problem of misconnection, is similar to a suggestion made in Halpern 2015 for evaluating counterfactual dependence in pre-emption situations (the similarity consists in the requirement to hold actual interactions fixed). Halpern, however, is not in the business of developing a process theory, but rather to specify within a structural equation approach the conditions which have to be held fixed to evaluate the conditional counterfactuals relevant for token causation. In section 7 I will briefly discuss the relation of the process theory presented here and the structural equations approach.

manner it did. Rather, an entirely different event would have occurred, one with a slightly different manner of shattering resulting from Billy's stone striking the window. Therefore, the actual effect does counterfactually depend on Suzy's throwing the stone and now late pre-emption brings no trouble for the necessity of counterfactual dependence for token-causation. Let me reply by pointing to how what I suggested above differs from what Lewis has discussed under the heading of 'extreme fragility'. According to this approach to the late pre-emption problem the right way to identify events and thus effects is by individuating them such that they could not occur at different times or in a different manner (Lewis 1986, 196-199). If the only way to individuate effects were fragile individuation then the problem of pre-emption wouldn't occur for the counterfactual account because the actual window's shattering would not be the same effect that the throwing of Billy's stone would have caused. However, that is not what I suggest. My suggestion is that we sometimes use fragile individuation and sometimes not. When we don't (e.g. when we consider the shattering of the window) we do have the problem of pre-emption and my suggestion is to classify the throwing of Billy's stone as an *irrelevant* interference for the non-fragile effect. However, we might also use more fragile individuation and ask why the shattering occurred in this particular manner. In that case the throwing of Billy's stone would be a *relevant* interfering factor. Whether or not an interfering factor is a relevant interfering factor is relative to the effect we are considering. In other words: The problem for the counterfactual approach would only dissolve if the only admissible events were fragile events, however, I admit both fragile and non-fragile events.

Fifth, whether or not the throwing of Billy's stone is a relevant interfering factor, i.e. a cause, depends on the individuation of the effect, as we have seen. By individuating the effect as an effect, we consider it to be a deviant state of a system that would have developed into another state, its quasi-inertial state at that time. If we consider as the effect *the shattering of the window*, we assume that there was a different state of the system (the window being intact) that it would have developed into had nothing interfered. If we consider as the effect *the particular manner of the shattering of the window*, we again assume that there was a different state of the system, its quasi-inertial state (another manner of the window being shattered), that it would have developed into had nothing interfered.

As discussed above (section 4.1) Blanchard and Schaffer criticise default relativity:

> As such default-relativity often seems to us to come close to a free parameter […], which basically gives the theorist leeway to hand-write the result she wants (Blanchard & Schaffer 2017, 192).

A similar remark may be thought to apply to the 'system-relativity' we have introduced. With respect to the example discussed above one might for instance object: What counts as the cause is highly dependent on how we choose to individuate the effect. Thus, it is presumably true that if we use the rich and detailed description of the effect, then Billy's throwing of the stone does count as (part of) what interferes with the quasi-inertial process (since we know in virtue of physical laws of interaction, conservation of energy, etc. that the window would not have shattered in that specific manner had it not been for the presence of Billy's stone right then and there). So, this system-relativity can generate whatever result the theorist desires willy-nilly, for all we need to do is choose the system *with a description of the effect in however much detail we need* to generate the result we are hoping for – either Suzy's throwing of the stone alone is a cause or Suzy-Billy's throwing together is a cause.
What this objection is missing is that a cause is always the cause of a particular effect. I don't see that there is a problem if the throwing of the stone by Suzy is a cause of the shattering of the window, while the throwing of the stones by both Billy and Suzy come out as contributing causes to the particular manner of the shattering. So the relativity that is relevant here amounts to no more than the fact that relative to effect A we have causes of a certain kind, while relative to effect B we have different causes.
Let me stress that the only agent-relativity that plays a role in this account is the one that is generated by the 'explanation seeking why-question' (van Fraassen 1980). Once the effect (the explanandum in the causal explanation, i.e. the effect and its contrast) is fixed, everything else is a matter of quasi-inertial processes and interferences into these processes. Whether or not these facts obtain does not depend on the agent's interest.

Sixth, Paul and Hall raise another worry that is relevant here: Suzy's stone relevantly interfered with the window to bring about its shattering, but so did *Suzy's and Billy's stones taken together*. That would give us the wrong diagnosis because Suzy's and Billy's throwing would both come out as causes of the shattering of the window in the pre-emption case. Thus, the two stones taken together ought to be excluded as a cause of the shattering. Paul and Hall worry that this cannot be done without relying on causal judgments, thus undermining the reductive program (Paul and Hall 2013, 111). As already mentioned, my aim is not to reduce causal facts to noncausal facts. Still, the account presented here needs to be augmented so as to exclude the stones taken together as a cause of the shattering. What needs to be added is some sort of minimality constraint.

As far as I can see every account of causation needs a minimality constraint, so I could simply argue that I do not need to go into this in any detail. However, a minimality constraint will have to do some extra work on my account of causation when it comes to symmetric overdetermination. So, while there is not enough space for a detailed account of a minimality constraint I will at least indicate how I would augment the account so as to deal with the problem. First I will help myself to the notion of a conjunctive event, which is an event that has 'parts' or conjuncts, which are events too. An example would be the conjunctive event consisting of the conjunct events of a throw and a sneeze, or *Suzy's and Billy's throws taken together* which consists of Billy's throw and Suzy's throw respectively. Furthermore I assume that there is (at least in the cases we are interested in) a natural decomposition of such conjunctive events. To minimalize a conjunctive event is to take away at least one of its conjuncts. A maximally minimalized relevant interfering factor for some effect e is a relevant interfering factor that has been shorn of all of those 'parts', without which it is still a relevant interfering factor for some effect e. Suppose Suzy sneezes while she throws a stone at the window. The conjunctive event of throwing and sneezing is a relevant interfering factor, but not a maximally minimalized relevant interfering factor. The throw without the sneeze is (presumably) a maximally minimalized interfering factor while the sneeze without the throw isn't.

So how do we determine whether a relevant interfering factor for a particular effect can be minimalized? We consider whether the effect in question would have been brought about if 'parts' or conjuncts of the relevant interfering factor had been eliminated. So the counterfactual we need in order to test whether we can minimalize a relevant interfering factor is the following: In the antecedent we consider a situation in which the relevant interfering factor has been shorn off of at least one 'part' (all the other interferences are as they are in the actual situation – except those interferences that occur as a consequence of the relevant interfering factor under consideration). In the consequent we specify the effect in question. If despite the elimination of the 'part' the counterfactual comes out as true the relevant interfering factor can be minimalized. It is important to notice that this is a two-step process. First we figure out the relevant interfering factors and in a second step these factors are minimized.

With this notion of a minimality constraint at hand we can give an augmented version of a definition of a cause (in the disruptive sense):

Let Z_i (t_2) be the state that a system S (at an earlier time t_1) is disposed to be in – provided nothing interferes between t_1 and t_2. Let e be the event of S being in state $Z_e(t_2)$ at t_2, where $Z_e(t_2) \neq Z_i(t_2)$.

(DC_{aug}) An event *c* is a $cause_{DC}$ of an event *e* iff *c* is the event of some maximally minimalized factor interfering with the quasi-inertial behaviour of system S between t_1 and t_2 such that S at t_2 is in state Z_e, rather than in state Z_i.

or (replacing the phrase "interfering factor … such that" by "relevant interfering factor"):

(DC_{aug}) An event *c* is a $cause_{DC}$ of an event *e* iff *c* is the event of some maximally minimalized relevant interfering factor with the quasi-inertial behaviour of system S between t_1 and t_2 for S at t_2 being in state Z_e, rather than in state Z_i.

All of this is fairly vague. For instance, the minimality constraint might be too restrictive. Suppose that Suzy's stone is a rather heavy stone. If she had thrown only one half of it, that would also have interfered with the quasi-inertial behaviour of the window and shattered it. Thus the throwing of the original stone would not count as a cause. I take this to be a serious worry, but I also think that there is a sense in which Billy and Suzy's both throwing, or Suzy's sneezing and throwing, are conjunctive but Suzy's throwing a single stone is not. This is the sort of distinction which seems natural but is difficult to make philosophically precise, but that might fit well with our ordinary language notion of causation.

Be that as it may, what I hope to have indicated is how the minimality constraint might work in cases in which we have clear intuitions.

Finally, symmetric overdetermination: Harry and Sally both throw stones at the window. Unlike in the previous case the stones reach the window in the very same moment. The windowpane shatters. If only one of the throws had occurred the windowpane would nevertheless have gone to pieces. The general verdict seems to be that both throws should be classified as causes. Traditional process theories have no problem with this case. However, it is my solution to the traditional process theory's problem of misconnection – namely the additional requirement that causes need to be *relevant* interfering factors – which seems to generate a problem for my account. According to the test for relevance I have introduced above neither Harry's nor Sally's throw is relevant.[8]

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[8] Thanks to Sebastian Schmoranzer and an anonymous referee for pressing this point.

However, the minimality constraint, which we have to introduce for independent reasons as we have just seen promises to solve this problem. Note that Harry's and Sally's throw taken together is a relevant interference with respect to the shattering of the window. But this conjunct event is not a maximally minimalized relevant interfering factor for the shattering of the window. Indeed, minimalizing yields two different maximally minimalized relevant interfering factors: Harry's throw on the one hand and Suzy's throw on the other. In other words, while the non-augmented definition of (disruptive) causation yields the wrong verdict (the conjunctive event is a cause but it's conjuncts aren't) the augmented definition, which incorporates the minimality constraint, classifies Harry's throw as a cause as well as Suzy's throw but not the conjunctive event. This seems to be the right result.

6 Disconnections

The problem raised by Paul and Hall (misclassification of pre-emption cases as cases of contributing causes) has been dealt with in the previous section. Along the way we have also explained how to distinguish relevant from irrelevant interferences (the problem of misconnection). So let us now turn to the problem of disconnection.

Absences seem to be causally relevant. For instance, the gardener's not watering the flowers caused the shrivelling of the flowers. There are many examples where absences cause, are caused, or are part of a process leading from the cause to the effect. Such 'negative causation' cannot be integrated into process theories that require the persistence of physical characteristics along a world-line that connects cause and effect (see Schaffer 2004 for an extended discussion). This is a problem for some process theories of causation, such as Dowe's and Salmon's, because on their account there is no causation without a physical connection in the sense of transmission of some amount of a conserved quantity (see, e.g., Dowe 2009). On the account involving quasi-inertial processes that I have presented, there is no analogous requirement and therefore the problem of disconnection is easier to cope with. Absences or negative events may, on my account, be integrated into quasi-inertial processes. This can be illustrated through the well-known case of double prevention:

> Suzy is piloting a bomber on a mission to blow up an enemy target, and Billy is piloting a fighter as her lone escort. Along comes an enemy fighter plane, piloted by Enemy. Sharp-eyed Billy spots Enemy, zooms in, pulls the trigger, and Enemy's plane goes down in flames. Suzy's mission is undisturbed, and the bombing takes place as planned. (Hall 2004, 241)

Suppose we want to say that Billy's pulling the trigger is a cause of the bombing of the target. Note that there is no continuous physical process leading from Billy's pulling the trigger to the actual bombing, and thus the Dowe-Salmon account has a problem here.

What I want to say about Billy's pulling the trigger as a cause is best presented by building up the quasi-inertial process from simpler cases. Let's start with a very simple situation. Suppose there are neither Enemies nor Billys around and we want to say that Suzy's bombing is the cause for the destruction of the target. In this case *the target sitting around peacefully* is the quasi-inertial process, which is disturbed by Suzy's interference, i.e., by the bombing. Consider now a second, different case: Enemy is around (but no Billy), and shoots down Suzy. We want to say that Enemy's intervention is the cause of the target's not being bombed (here the effect is a negative event). In this case we consider a different quasi-inertial process, viz., *Suzy bombing the target*. This quasi-inertial process is interfered with because Enemy prevents Suzy from bombing the target. Finally, add Billy to the picture: Billy shoots down Enemy, and the quasi-inertial process we are considering in this case is even more complex: It is *Enemy preventing Suzy from bombing the target*. This process is interfered with by Billy's pulling the trigger. Billy's pulling the trigger is therefore the cause for the quasi-inertial process *Enemy preventing Suzy from bombing the target* not taking place and thus a cause of the bombing of the target. So even though there is no continuous physical process leading from Billy's pulling the trigger to the actual bombing, on our account we can explicate why Billy's pulling the trigger might be considered as a cause of the bombing of the target. What this case illustrates is that quasi-inertial processes may comprise negative events.

Negative events may not only be part of quasi-inertial processes, they may also serve as causes or effects. Let me briefly comment on this issue. We have already mentioned a negative event that was an effect, viz., the bombing not taking place. When we classify absences (or negative events) as effects we are (implicitly) stating that a certain positive event—the bombing of the target—which would have been part of an undisturbed quasi-inertial process does not take place. The case of absences as causes is trickier. Consider the case where my neighbour Peter's not watering my flowers while I was on holiday caused the flowers to shrivel. What we are considering as a quasi-inertial process is the flowers living their usual life, with enough oxygen, and watered regularly by Peter so that they flourish. Why is it that the quasi-inertial process is not displayed? Because Peter did not water the flowers. So we consider Peter's not watering the flowers as the interfering factor.

To sum up: Because the account presented here does not require the persistence of physical characteristics negative causation does not pose a special problem for this kind of process theory.

7. Relation to Other Theories of Causation

Process theories of Causation

I argued that the application of token-causal terminology can be best understood if a cause is taken to be an interfering factor to the quasi-inertial behaviour that a system is disposed to display. This is a claim about processes because the quasi-inertial behaviour concerns the temporal evolution of a system (e.g. the process that is described in Newton's first law). So how exactly is this view related to traditional process theories?

Process theories tend to take "causation to be the transfer or persistence of properties of a specific sort." (Dowe 2009, 214). The quasi-inertial processes we have talked about can indeed be characterised in terms of the persistence of properties: The behaviour in question is persistently manifest as long as nothing intervenes. Process theories consider interferences with these processes as cases of causation. Thus far I agree. There are, however, two important points of disagreement: First, according to the definition (DC) of the disruptive concept of causation the processes themselves do not constitute cases of token causation (though they are causal processes in the sense of closed system causation (see section 2). A statue being at a certain place at 2pm today is not a cause of its being there at 5pm according to this definition. Therefore I do not talk about *causal* processes but rather about *quasi-inertial* processes. Second, the characterisation of the relevant processes and disturbances (interactions) is different. Whereas Dowe and Salmon define these processes either by the mark criterion or in terms of invariant or conserved quantities (Dowe 2009 provides an overview), I characterise them in terms of the underlying systems' dispositions. A ball rolling on a flat surface is described by traditional process theorists as a causal process because it conserves kinetic energy and momentum. I characterise it as a quasi-inertial process, because it manifests a behaviour it is disposed to display, unless it is disturbed, namely the one that is attributed to it in Newton's first law. Having certain invariant /conserved physical properties is thus not necessary to qualify as a quasi-inertial process. The essential question is whether or not the relevant system is disposed to display a certain behaviour, and determining this is the responsibility of the sciences: It is for the physicists to decide whether or not bodies have the disposition to continue in uniform rectilinear motion if no forces are impressed on them.

Similarly it is for economists to decide whether or not an economic system in which inflation rises will yield higher unemployment-rates (if nothing interferes).

The account of causation in terms of quasi-inertial processes and inferring factors is thus able to deal with all three issues that Dowe (2009) has identified as major problems for process theories. The first one is what he calls 'the problem of reduction': Because the account presented here allows for causal relations obtaining at various 'levels', it is not committed to the claim that all causation is ultimately physical causation. The second issue is the problem of negative causation ('the problem of disconnection'), which we have dealt with in section 6. The third issue concerns what has been called the 'problem of misconnection': Some interactions or interferences do not qualify as cases of causation. We have dealt with this problem by distinguishing relevant from irrelevant interferences.

Dispositional Accounts of Causation

I explicated causation as an interference with a quasi-inertial process that a system is disposed to display. The account provided can thus be read as *disposition-based* process theory (see Hüttemann 2013). This characterisation raises the question how the account presented here is related to other dispositional accounts. According to the best-known dispositional account of causation a cause is simply a disposition manifesting itself (Mumford & Rani 2013). This characterisation of causes falls out of the definition of dispositions if the latter are defined as properties that are oriented towards certain causal effects. There is not enough space to discuss the pros and cons of this account. I just want to point to two differences between this account and the one presented above: First, while according to the disposition-as-causes account a cause is a disposition that manifests itself, what is essential to the account presented above is a disposition whose manifestation is interfered with (see Mumford 2014, 337). Second, because I do not build causation into the definition of dispositions, my account of causation allows for the position that causation is essentially a macroscopic feature that need not be implemented at the micro-level, even if there are dispositions at the micro-level.

Structural Equations Accounts

Much of recent work on causation has been done within the structural equation framework. The structural equations approach has become influential as a device for causal inference in the social sciences, psychology, medicine and other disciplines that need to infer from probabilistic correlations to causal structure (Pearl 2000, Spirtes, Glymour and Scheines 2000). While causal models (which rely on structural equations) are, in the first place, a way of *representing* causal structure, in the philosophically oriented literature they have also been invoked to *define* causation (Hitchcock 2001, Woodward 2003, Halpern & Pearl 2005, Halpern 2015).

Various authors working in this framework have attempted to define token causation (actual causation) as part of this overall approach. Within the structural equations approach actual or token causation is usually spelled out in terms of conditional counterfactual dependence, where the truth values of the counterfactuals are determined by the structural equations. The accounts typically differ with respect to the condition that has to be held fixed while evaluating counterfactual dependence. As an example consider Woodward's definition of actual causation:

> "(AC1) The actual value of X=x and the actual value of Y=y." (Woodward 2003, 77)

This first condition simply states that for an event which consists in variable X having the value x to be the cause of the event of variable Y having the value y, both these events need to be actual.

Woodward's second condition runs as follows:

> "(AC2*) For each directed path P from X to Y, fix by intervention all direct causes Z_i of Y that do not lie along P at some combination of values with their redundancy range. Then determine whether, for each path from X to Y and for each possible combination of values for the direct causes Z_i of Y that are not on this route and that are in the redundancy range of Z_i, whether there is an intervention on X that will change the value of Y. (AC*2) is satisfied if the answer to this question is "yes" for at least one route and possible combinations of values with the the redundancy range of the Z_i". (84)

The notion of a redundancy range is explained as follows:

> "The values v_1, …v_n are in what Hitchcock calls the *redundancy range* of the variables V_i with respect to the path P if, given the actual value of X, there is no intervention that in setting the values v_1, … v_n, will change the actual value of Y."

Crucially once you invoke the notion of conditional counterfactual dependence by relying on redundancy ranges (or something in the vicinity – the exact details are still debated; for a recent discussion see, for instance, Halpern 2015) you will get correct results in problematic cases, e.g., in pre-emption cases. The basic idea is that you fix the value of potential back-up causes, which intuitively do not contribute to the effect (such as Billy's stone) in such a way that their non-contribution is held constant. Given that, you check whether the effect depends counterfactually on the other cause (-variable) i.e. Suzy's stone, and it does.

What is essential here is that all the work is done by the redundancy range which has been added to yield the correct results. Nothing in the structural equations framework motivates adding this feature.[9] By contrast, from the perspective of disruptive causation it is easy to motivate why one should rely on a redundancy range (or something in the vicinity): Satisfying the condition that the values of the other possible causes be in the redundancy range is tantamount to saying that nothing interferes with the process leading to the effect-variable Y having a certain value. In other words you consider how the system that is characterised in terms of Y would behave provided there are no interfering factors, that is: its quasi-inertial behaviour. You then consider whether an intervention on X interferes with Y's quasi-inertial behaviour. Thus, in order to get from structural equations to actual causation you have to add – e.g. via the redundancy range – the disruptive concept of causation.
The account of disruptive causation presented here may thus serve as a motivation for a definition of token causation in the structural equations framework and thus to complement it.

8. Conclusion

The account of causation in terms of quasi-inertial processes and inferring factors that has been developed here has been shown to be able to deal with the traditional problems that process theories have to face, namely the problem of misconnection and the problem of disconnection as well as with the problem that has been raised by Paul and Hall (2013), namely the misclassification of pre-empted causes as contributing causes.

References

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[9] Paul & Hall when discussing conditional counterfactual accounts of causation formulate the following desideratum: "What principles determine the selection of the fact F to be held fixed?" (Paul and Hall 2013, 112)

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