

States, Processes and Events, and the Ontology of Causal Relations

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Abstract. The subject of causality is large, and fraught with difficulties. In this paper, we concentrate on two aspects which are of importance when we seek to handle causality from an ontological point of view. The first concerns the range of particulars between which causal and causal-like relations may hold. In addition to events — the domain most typically chosen as the objects of causation — we consider the role played by processes and states, taking a particular view of the nature of these entities. The second aspect concerns the range of different causal and causal-like relations to be considered. In addition to causation itself we consider such things as initiation and termination, perpetuation, enablement and prevention. We do not present a fully-fledged ontological theory of causation, but lay down some basic ingredients that should be taken into account in the construction of such a theory.

Keywords. Causation, causal relations, states, processes, events, granularity

Introduction

The notion of ‘cause’ has been debated by philosophers and scientists for centuries, and the accumulated literature on the subject is vast. It is therefore with some trepidation that I venture to say anything about it at all. It is, however, remarkable that in all the previous FOIS conferences there has only been one paper presented with any of the words ‘cause’, ‘causal’, ‘causality’, or ‘causation’ in its title [17], and since its inception, the journal *Applied Ontology* has contained *no* article with any of these words in its title. Of course, there are other words whose meanings are closely associated with the notion of causality — ‘effect’, ‘agency’, ‘function’, for example — many of which *have* occurred with greater frequency in the applied ontology literature, and it is undeniable that causality and related notions constitute an ever-present undercurrent in almost any ontological theorising that engages seriously with the temporal dimension.

Theorising about causation and causality tends, naturally enough, to focus on the formulation and meaning of causal *laws*, which capture certain types of regularities relating the occurrence of different kinds of events. Such laws play a role in diverse activities such as prediction, retrodiction, diagnosis, and explanation, and the formulation of such laws may make use of techniques such as modal logic [18], probability theory [24], ‘qualitative differential equations’ [16], qualitative process theory [5], and non-monotonic reasoning [25]. All such accounts must handle causality at the level of types rather than tokens: the relations involved express logical or physical constraints on the co-occurrence

of events or processes of specified types. Of course the actual co-occurrences involve tokens, but it seems that their explanation must always refer to types.

My aim in this paper is more modest: my target is not general causal laws, but individual instances of causation as they occur in the world. Thus I am working within an ontology of particulars, both particular entities and the particular relationships holding between them. Although these entities — states, processes, and events — are traditionally classified as perdurants or occurrents, I shall take the view that states and, on the relevant understanding of that term, processes are in many ways more like continuants than occurrents [7,8]. My aim is not to explain what it means to say that one thing causes another (which has been the main focus of the philosophical tradition in this area) but to clarify the ontological relationships amongst a family of related causal-like notions, expressed by verbs such as ‘initiate’, ‘perpetuate’, ‘allow’, and ‘prevent’.

1. Philosophical Background

Many philosophers have written at length on the subject of causality,¹ and amongst those writing in the latter part of the twentieth century, the work of Donald Davidson has been highly influential. In particular he is noted for his stance on three key issues which play an important part in what follows, namely:

1. What are the elements that are being related by causal relations?
2. Do causal relations relate universals or particulars?
3. What is the relation between causation and causal explanation?

Everyday discourse has a number of distinct ways of expressing facts about causation, for example:

- (a) The accident was caused by a lorry-driver.
- (b) The accident was caused by the driver’s braking suddenly.
- (c) The accident was caused by the fact that the traffic was heavy and the road was icy when the driver braked suddenly.

Here one and the same event is said to be caused by (a) an object, (b) another event, and (c) a fact, providing three distinct answers to question 1.²

Regarding (a), it is natural to ask *how* the lorry-driver caused the accident: objects can only cause things by *doing* something. Thus (a) might be regarded as really saying that the accident was caused by something the lorry-driver did, in other words by an event, as illustrated in sentence (b).

With (b), it is often objected that the driver’s braking suddenly cannot be the whole cause of the accident, since sudden brakings by drivers do not in general cause accidents. They only do so under particular conditions, such as those spelt out in (c); the true cause is not just the driver’s sudden braking but the braking together with those conditions.

Davidson [3] has a ready response to this, criticising J. S. Mill for thinking that “we have not specified the whole cause of an event when we have not wholly specified it”.

¹ See, e.g., the papers collected in [26].

² Kim [14] lists other categories that may play this role: “We often take *events* as causes and also as effects; but entities of other sorts (if indeed they are ‘other sorts’), such as *conditions*, *states*, *phenomena*, *processes*, and sometimes even *facts*, are also pressed into service when we engage in causal talk, although with these there is some controversy as to their suitability as terms of causal relations.”

His point is that the sudden braking by the driver, cited in (b) as the cause of the accident, occurs at a particular time and place, and as such it *is* a braking by the driver at a time and place when the traffic was heavy and the road was icy. There is no need to combine the braking with the heaviness of the traffic and the iciness of the road in order to specify the ‘true’ cause. Sudden brakings in general do not cause accidents; this one did. It did so because it occurred against the background of a set of conditions of a kind in which sudden brakings *do*, in general, cause accidents. Thus according to Davidson causation is a relation between particular events; and the fact that one event caused another is independent of how the events are described. This provides an answer to question 2.

None the less, there is an important role for universals in statements of causality. Lehmann *et al.* [17] distinguish between “*causality*, a law-like relation between types of events, and *causation*, the actual causal relation that holds between individual events”. They capture the former type of relation through ‘causality dependences’, relating *types* of change that objects can undergo, and then use such dependences in specifying the conditions that must hold between two particular events in order for it to be the case that a causation relation holds between them (i.e., one caused the other).

Universals are important because of their role in *causal explanations*. A particular event — this braking by this driver — caused the accident, but to explain *why* it had that effect we must refer to the properties that fitted it to play the role of the generic event-type specified in a *causal law* of the form ‘If a lorry-driver brakes suddenly, and [various background conditions hold], then an accident will ensue’. In general, the *facts* of causality consist in simple causation relations between token events, e.g., E_1 is the cause of E_2 ; but an *explanation* of this fact makes reference to a general law to the effect that any event sufficiently similar to E_1 would, if sufficiently similar background conditions obtain, cause an event similar to E_2 . One of the difficulties of formulating causal laws is knowing just what ‘sufficiently similar’ means. This points towards an answer to question 3, though elaboration of the details is fraught with difficulty.

One event’s causing another is the paradigmatic causation relation, analysis of which has caused philosophers such headaches. In this paper I am not concerned with the analysis of *what it means* to say that one event caused another, but rather take this as a primitive relation. Causation of one event by another does not, however, exhaust the ways that causality is manifested in the world, and my main task in this paper is to elucidate the relations between this paradigmatic case and a family of related notions concerned with various kinds of causal-like dependencies amongst states, processes, and events.³

2. The Role of States in Causation

The notion that both events and states can be involved in causal relations goes back a long way. Mill [20] discusses the case of a man who dies as a result of eating a particular dish. Noting that eating such a dish is not invariably fatal, he claims that the eating of the dish cannot be *the* cause of the death, but rather just one of a number of conditions — e.g., relating to the man’s state of health at the time — which conjointly caused the death. In particular, he notes that “the various conditions, except the single one of eating the food, were not *events* ... but *states*”, and uses this to explain why we tend to single out the event as the cause rather than the conjunction of the event and the other states.

³This work develops further some ideas originally suggested in [9].

As noted in §1, Davidson held that, on the contrary, the eating of the dish *is* the whole cause, but its effectiveness as a cause depends on the presence of ‘standing conditions’ which are not themselves causes. While Mill includes conditions as part of the cause of an event, Davidson distinguishes the cause (an event) from the preconditions (states) that allow the cause to have the effect that it does. Steward [27], likewise, is bothered by the use of states in the ‘causal networks’ proposed for modelling causal relations in the *mental* sphere. As well as event tokens, such models need to invoke ‘state tokens’ as causally efficacious elements, and Steward finds the notion of state token problematic.

The notion that states can be causally efficacious does indeed raise considerable difficulties. A state is generally regarded as something passive, whereas anything that can cause an effect must surely be in some sense active. On its own, this observation is merely indicative that there is something wrong with the idea of a causally efficacious state, but we can make this more precise as follows. Suppose some state *S* causes event *E* to occur at time *t*. We consider two possibilities: either (1) *S* already holds over an interval $\langle t', t \rangle$ immediately preceding *t*, or (2) *S* holds at *t* but *not* during some interval immediately preceding *t*. In case (1), we can ask, if *S* already held over an interval leading up to *t*, why did it not cause *E* earlier than it did?⁴ If *S* was sufficient to cause *E* at *t* then it must surely be sufficient to cause *E* at *t'*, for otherwise we would have to find some relevant difference between *t'* and *t* to explain why *E* was caused at the later time but not at the earlier. This relevant difference can only consist of something happening between *t'* and *t* (e.g., some other state's coming to hold, or the value of some variable passing a critical threshold), and in that case we can argue, in a Davidsonian spirit, that it was *this* happening — an event — which is the true cause of *E*, the state *S* being relegated to the status of a background enabling condition. Similarly, in case (2), the cause of *E* is not the state *S* itself, but the event of its starting to hold.

If we accept this kind of argument, then it is natural to say, in the case of the accident happening because of the icy conditions, that the icy conditions in themselves (a state) cannot possibly cause an accident; rather, the accident was caused by some manoeuvre by the driver, and the role of the icy conditions is to enable that manoeuvre to give rise to an accident — it being supposed that an exactly similar manoeuvre under non-icy conditions would not, in general, cause an accident. The question we now face is whether this enabling role of states belongs purely within the sphere of causal explanation, or whether it points to an actually existent feature of reality on a par with the causation relation between the driver's manoeuvre and the accident.

The cardinal difficulty here is to identify something in reality that corresponds to the problematic notion of *state token*, something which can sit alongside the (relatively!) unproblematic category of *event token* in our ontology. To see the difficulty, consider what can be meant by ‘the state of the road at the time of the accident’. If the road was icy and congested at the time of the accident, then it must have been in this state for some period leading up to that time. To be definite, suppose the road became icy at time *t*₁ and became congested at *t*₂, and the accident happened at *t*₃.⁵ Now there seem to be two

⁴Here we are invoking the Principle of Sufficient Reason — like Leibniz asking why God would choose to create the world when he did, rather than at an earlier time (an argument against the absolute existence of time independent of any actual changes taking place).

⁵Of course, being icy and congested are not simple ‘all or nothing’ predicates: there are degrees of iciness and congestion. For now, however, we suppose that some particular degree of each has been specified as the threshold above which the road is to count as having that property, and below which, not.

mutually inconsistent ways in which we talk about states: on the one hand, we might say that (1) the state of the road *changed* at t_1 and t_2 ; on the other hand, we might say that (2) the road was in *different* states before t_1 , between t_1 and t_2 , and after t_2 . The former way of talking seems to imply that there is one thing, the state of the road, which has different properties (e.g., a degree of iciness, a degree of congestion) at different times; ontologically, it is a continuant particular specifically dependent on the road, its lifetime being temporally coextensive with that of the road. The identity of the state of the road, on this account, is neither more nor less problematic than the identity of the road itself. The second way of talking, (2), posits a multiplicity of road-states, which come into being and pass away, e.g., a state of iciness which comes into existence at t_1 and a state of congestion which comes into existence at t_2 . For this kind of state the identity conditions are more problematic. It seems natural to regard the iciness which starts at t_1 and endures up to the point when the ice has disappeared as a single state instance, a different token from the iciness which affected the same road three days earlier, say. On the other hand, we readily say things like ‘the road is in the *same* state now as it was three days ago’, even when it was in a different state in the intervening period. To reconcile these two accounts, we must assume that ‘the same state’, in the latter locution, refers to a state type rather than a state token.

Perhaps a more pressing worry concerns the apparent dependence of this kind of state on the words we use to describe it: for such states to play a role in causation as such, and not just in causal explanations, they must have a reality that is independent of human thought and language, in conformity with Davidson’s insistence that the causal relation between two individual events must be independent of how we choose to describe them. If states are too tied to language, they would seem to partake of the nature of *facts*, and as Steward [27, p.163] puts it, “it might be said that since facts are not part of the natural world at all, they cannot . . . be said to bear causal relations to anything at all”.

Despite these reservations, for the purpose of understanding the role of states in causality, this second notion of state seems to provide the clearest way forward. It allows us to say, for example, that a freezing event simultaneously initiates a state of iciness and terminates a state of non-iciness. The state of iciness then allows some manoeuvre by the lorry-driver to cause an accident. This way of speaking seems to be quite natural, and at the same time seems to imply an ontological commitment to such things as a state of iciness which can stand in at least two kinds of relation to events (as indicated by ‘initiated by’ and ‘allows’). In the next section I shall illustrate this using a simple everyday scenario of a person entering a house.

3. Causal (and other) relations involving states and events

Figure 1 illustrates the following scenario. Initially, a person is outside a house, at the front door. The door is shut, and locked. The person turns the key, thereby unlocking the door; this allows her to open the door by pushing on it. The result is that the door is then open, which allows her to enter the house by walking forward through the doorway. In the diagram, states are shown as rectangular boxes, and events as diamond-shaped ones. There are several different causal or causal-like relations here. There are two clear cases of *causation* between events: the person’s turning the key causes the door to become unlocked, and her pushing the door causes it to open. There are several *initiation* and

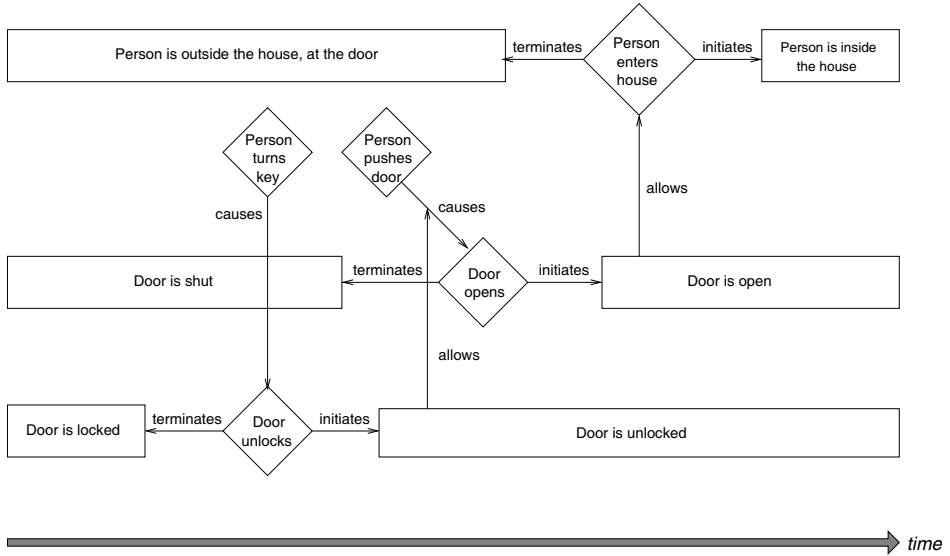


Figure 1. Causal and causal-like relations for a person entering a house.

termination relations between events and states, e.g., the unlocking of the door (an event) terminates a state of lockedness and initiates a state of unlockedness. Finally, there are two *allows* relations between states and events: the unlockedness of the door allows the door-pushing to cause the door-opening, and the openness of the door allows the entering. Note that the first of these is presented as a relation between a state and a causation relation, the second between a state and an event. In fact ‘The person enters the house’ contains a hidden causation: the person tries to move forward and this causes her to enter the house — but only because the door is open. The ‘allows’ relation here is pointing to the causation relation concealed within the event description.

The four relations of causation, initiation, termination, and allowing are illustrated in Figure 2. While these all belong in the general semantic field of causality, it does not seem appropriate to call them all *causal* relations. That an unlocking event initiates a state of unlockedness is not a case of cause and effect; rather, it is a direct consequence of the logic of unlocking: for the door to become unlocked is by definition for it to enter a state of unlockedness — by contrast, the door’s becoming unlocked is logically independent of the key’s being turned, the relation between them being one of contingent causation. The relation denoted by ‘allows’ is likewise not one of causation, as discussed above: the door’s merely being unlocked does not in itself cause anything, but it does allow the pushing event to cause the opening event. Therefore apart from ‘causes’, I call these relations ‘causal-like’ rather than ‘causal’.

These causal-like relations have a clear affinity with Kim’s ‘non-causal connections’ [15]. If a married man dies, his wife becomes a widow; Kim regards these as two different events, with the latter dependent on, but not caused by, the former. In our analysis we would say that someone’s becoming a widow initiates their *being* a widow, but we do not have separate terms for the relation between the husband’s dying and either of these two events. Kim also considers cases such as the following: I turn the key in the ignition,

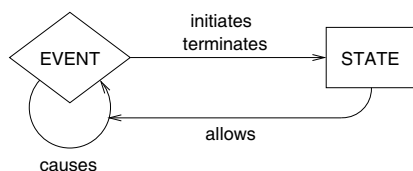


Figure 2. Causal and causal-like relations between states and events.

thereby starting the engine. The key's turning causes the engine to start, but my turning the key does not *cause* me to start the engine. This would be a case, for Kim, of 'non-causal determination'. Non-causal determination of this kind is often expressed using 'by': I start the engine *by* turning the key. He uses the term 'results in', borrowed from [31], to express the relations between my turning the key and the turning, and between my starting the engine and the engine's starting.

In relation to this, it should be noted that our Figure 1 does not contain anything explicitly labelled as 'Person opens door'. Instead, we have 'Person pushes door' causing 'Door opens'. Where in this analysis do we find the event of the person opening the door? There are two possible answers here. One answer is to say that the person's opening the door is the very same event as her pushing the door.⁶ The other answer is to say that the opening of the door is a *composite* event consisting of the person's pushing together with the door's opening; in this case the pushing of the door is a *proper part* of the opening of the door. Cases like this have been discussed extensively in the philosophical literature, with, for example [1,4,2,13] all favouring the former type of answer, and [29,10,28,15] all favouring the latter — as we have seen, Kim [15] would say that the person's pushing on the door non-causally determines their opening it. There are fairly persuasive arguments either way, but the main thing to note for our present purposes is that our analysis in Figure 1 is neutral with respect to this question.

A similar issue arises with the person's turning the key causing the unlocking of the door. Under a more detailed analysis, similar to that of Kim, we could say that the person's turning the key results in the key's turning, which causes the door to unlock. We could add that the person's turning the key determines, in Kim's sense, their unlocking the door: they unlock the door by turning the key.

4. Processes

The next example I shall consider introduces a further complication. Over a certain interval i , a wheelbarrow moves from position A to position B. What caused the wheelbarrow to move? The gardener pushed it, all the way. What exactly causes what here? There was a pushing event and a moving event, and both took up the interval i . Did the pushing event cause the moving event? Suppose we say that the pushing event *as a whole* caused the moving event *as a whole*; what exactly does this mean? Both events consist of temporal parts, and the causal relation distributes over the parts. If the pushing event is divided into n equal phases P_1, P_2, \dots, P_n and the moving event into n equal phases

⁶That is, this particular pushing was also an opening, since the door did in fact open as a result of it; there is no claim that *all* door-pushings are door-openings.

M_1, M_2, \dots, M_n , then it is natural to say that for each i , P_i causes M_i . But the number of subdivisions can be made as large as we like; in the limit, we seem to want to say that the pushing that was taking place at any moment t during the interval i is the cause of the moving that was taking place then. We are no longer talking about events: pushing and moving that are going on at an instant cannot be considered to be events. Rather, they are *processes*.

The word ‘process’ has been used in so many different ways that it should be obligatory for anyone using this term in an ontological discourse to explain exactly what they mean by it, and how it differs from ‘event’. An event, as I use the term in this paper, is a temporally bounded occurrence typically involving one or more material participants undergoing motion or change, usually with the result that at least one participant is in a different state at the end of the event from the beginning. Events are usually identified with reference to an *event type*, e.g., the statement ‘John baked a cake yesterday’ identifies a particular event as an instance of the type ‘cake-bakings by John’ (itself a subtype of the cake-bakings generally), pinpointing a particular instance as the one which took place yesterday. I take it that all this is relatively uncontentious.

Now one might say that baking a cake is a *process*, whose individual completed instances are events. This is a common use of the term, encompassing even highly complex processes such as the manufacture of a motor car from raw materials all the way to the finished product. Elsewhere [7] I have called these *closed processes* or *routines*; they are the kind of process that is handled by various process algebras or process calculi (e.g., the π -calculus of [21], or the process specification language PSL [11]). Because this kind of process usually has well-defined beginning and end points, there is a clear affinity with events: each individual car, for example, resulted from an event which was one complete instantiation of the generic car-manufacturing process.

In this paper, I reserve the term ‘process’ for something which has greater affinity with *states*. A process in this sense is an *open-ended, homogeneous activity*, such as a person’s pushing a wheelbarrow, or writing — not specifically writing a book, or a letter, but just engaged in the activity of putting pen to paper and generating written words in sequence. Other examples, not involving human participants, are the ongoing process of photosynthesis in which a leaf participates so long as there is sunlight (or a suitable substitute) available, the falling of the rain, and the flowing of a river. In the well-known classification of Vendler [30], these are called ‘activities’.

A process might be regarded as a *dynamic state* — a state of change, involving continuous change in some attribute of one or more of its participants. Both states and processes can be regarded as present at individual moments of time, in contrast to events, which normally inhabit extended intervals.⁷ But unlike states, processes can in themselves be causally efficacious, as the barrow-pushing example shows: the pushing process does give rise to the movement of the barrow.⁸

Causal relations between processes differ from causal relations between events in an important way. To cause something to move is to bring it about that it moves, but

⁷That is why processes are classed with states as ‘stative perdurants’ in DOLCE, where ‘stative’ is not to be understood as meaning the same as ‘static’. But whereas DOLCE classes states as perdurants, i.e., occurrents, BFO regards them, more correctly in my view, as continuants, i.e., endurants. If processes are state-like, perhaps they too should be classified as continuants. For the view of states and processes as continuant-like entities, see [6,7,8]. The notion of process is here putting the distinction between continuants and occurrents under strain.

⁸There is a voluminous literature on the ontology of states, processes, and events, which it is no part of my purpose to review here — see for example [23,22,19].

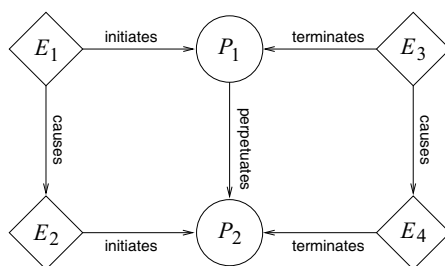


Figure 3. Causal and causal-like relations amongst states and processes.

the pushing at time t does not *bring it about* that the wheelbarrow moves; rather, it *perpetuates* a pre-existing motion. I propose, therefore, that the causal relations involved in the barrow-pushing scenario should be analysed as follows:

- Event E_1 : At t_0 , the gardener starts pushing the wheelbarrow.
- Event E_2 : At t_0 , the wheelbarrow starts moving.
- Process P_1 : Throughout (t_0, t_1) , the gardener is pushing the wheelbarrow.
- Process P_2 : Throughout (t_0, t_1) , the wheelbarrow is moving.
- Event E_3 : At t_2 , the gardener stops pushing the wheelbarrow.
- Event E_4 : At t_2 , the wheelbarrow stops moving.
- Event E_1 causes event E_2 .
- Event E_1 initiates process P_1 .
- Event E_2 initiates process P_2 .
- Process P_1 perpetuates process P_2
- Event E_3 causes event E_4 .
- Event E_3 terminates process P_1 .
- Event E_4 terminates process P_2 .

This analysis is illustrated diagrammatically in Figure 3, in which I introduce the convention that processes are represented by circles (or sometimes ellipses).

Notice that I am using ‘initiates’ and ‘terminates’ here as relations between events and processes, whereas in §3 they were relations between events and states. This is in keeping with the ‘stative’ or endurant character shared by both states and (this kind of) processes. Similarly, the ‘allows’ relation between states and causation relations can be extended to encompass relations between states and perpetuation relations. To illustrate this we turn to another example.

Figure 4 presents an analysis of the simple scenario in which a person (call him ‘I’) throws a ball. The analysis should be largely self-explanatory, but note the following points. My holding the ball (a state) allows both the causation relation between my hand’s starting to move and the ball’s starting to move, and the perpetuation relation between the continuing motion of my hand and the continuing motion of the ball. Once I let go of the ball, so that I am no longer holding it, the motion of my hand no longer has any causal-like relation with the motion of the ball; but the motion of the ball now perpetuates *itself* (Newton’s first law of motion!), this being allowed by the fact that I am now *not* holding the ball. Thus the ‘ball is moving’ state is divided into two phases, the first, before I let go of the ball, being perpetuated by the motion of my hand, and the second, after I let go,

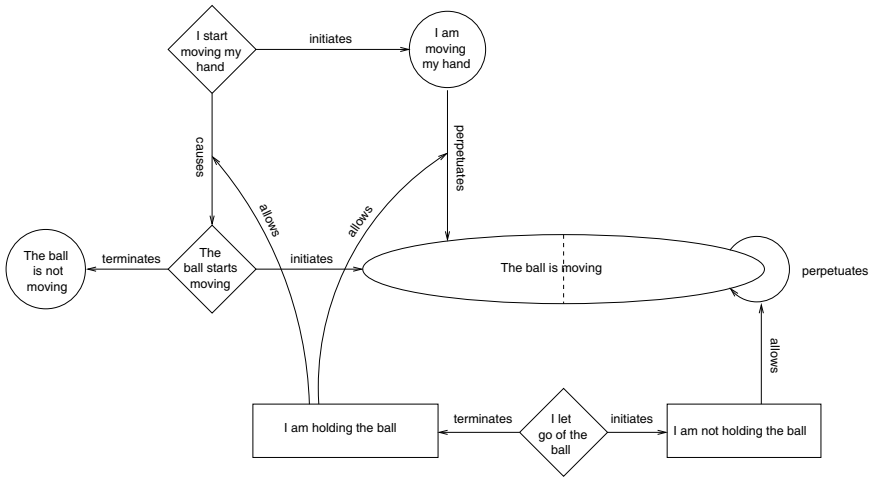


Figure 4. Causal and causal-like relations for a person throwing a ball.

being self-perpetuating. Since this analysis does not refer to acceleration, it is physically naive; but not on that account incorrect.

5. Granularity

It is a widely acknowledged that the world and its contents can be described at many different levels of detail, and the ontological analyses appropriate to different levels of detail may be significantly different. A familiar example is the philosopher's table-top, which at the macroscopic level of human experience is correctly described as a solid block of wood, but at the subatomic level is equally correctly described as an immense collection of protons, neutrons, electrons and other particles separated by relatively vast expanses of empty space. But even much less extreme shifts in granularity can have interesting ontological consequences.

Quite often, what appears at one granularity level as a process may, when described at a finer granularity, be seen as a sequence of events. This idea surfaces repeatedly in the literature on temporal knowledge representation and ontology; we see it, for example, in the characterisation of a process as “a functionally coherent aggregate of one or more transitions and subprocesses” in [12]. There, admittedly, the kind of process referred to is the closed kind (referred to as ‘routines’ in §4), but the same idea can be applied to the kind of homogeneous processes represented by circles and ellipses in the diagrams in this paper. The homogeneity characteristic of this kind of process is usually relative to an appropriate level of granularity — and indeed, it seems plausible that the cognitive salience of a given granularity level may derive precisely from the fact that, at that level, certain complex temporal phenomena acquire the homogeneity that allows them to be apprehended as simple processes. Unless they are absolutely homogeneous, i.e., appearing homogeneous at arbitrarily fine levels of granularity, processes of this kind can also be covered by the definition in [12], since under granularity refinement their apparent homogeneity shows up as *repetition* of some basic event type.

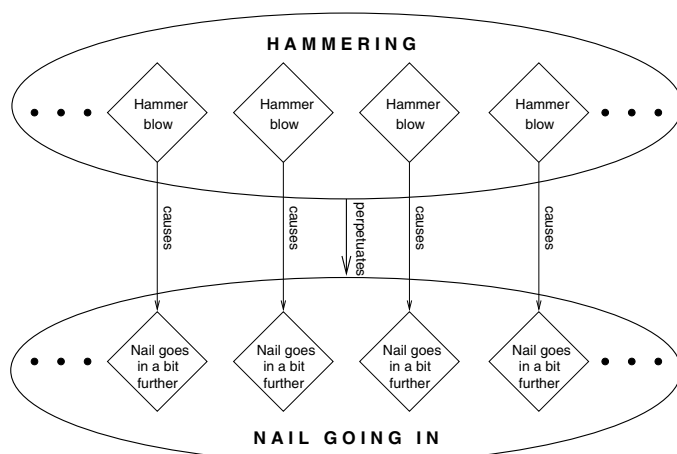


Figure 5. Processes at coarse granularity resolved into event-sequences at finer granularity.

The next example gives a simple illustration of this, and how it fits into our framework. Consider a person hammering in a nail. So long as he keeps hammering, the nail keeps penetrating further into the wood (until, of course, the nail is in as far as it can go, after which a condition obtains which prevents further hammering from driving the nail inwards). We thus have a process P_1 (the hammering) which perpetuates a process P_2 (the nail penetrating the wood). Now in fact the hammering consists of a sequence of blows and the nail penetrating the wood consists of a sequence of events each of which may be described as ‘the nail goes a little further into the wood’. We thus have the picture that is illustrated in Figure 5, where both levels of granularity are presented simultaneously, with the processes of hammering and the nail going in represented as large ellipses within which may be seen the sequences of events into which these processes are resolved when examined at a finer level of granularity. The perpetuation relation between the processes similarly resolves into a sequence of individual causation relations between the respective hammer blows and incremental nail motions.

The perpetuation relation holds between processes, but a similar relation can exist between a process and a state. An example is the operation of a boiler which maintains the water at a particular temperature. The water’s being at 50°C, say, would normally be regarded as a state rather than a process; and while it does not sound entirely wrong to speak of perpetuating a state, it is useful to recruit another term here, and for this we shall use *maintain*, as in the previous sentence. Just as some processes can be resolved into event sequences under granularity refinement, so some states may show up as having a process-like aspect — e.g., the supposedly constant temperature of the water may on close examination be seen to result from many fine adjustments where the water temperature repeatedly dips below or shoots above the targeted average, and this oscillation is a process rather than a state (and the individual cycles of the oscillation are events).

Can a *state* maintain another state? In the realm of causal explanation it certainly seems so. Why does the lamp remain at a height of 2.2 metres above the floor? Because it is suspended from the ceiling by a cable. The cable is in a state of tension because of the weight of the lamp it supports. The continuing presence of the cable maintains the continuing presence of the lamp in its position 2.2 m above the floor, its weight exactly bal-

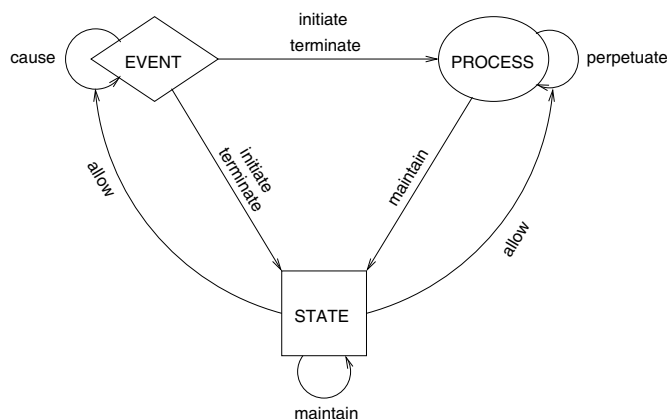


Figure 6. Causal and causal-like dependencies amongst states, processes and events.

anced by the tension in the cable. At the macroscopic level these ‘continuing presences’ are unequivocally states; only by proceeding to the level of atoms and molecules can we see them as the resultant of many small-scale interactions, and thus resolve the maintenance relation between the state of the cable and the state of the lamp into a perpetuation relation between the processes enacted by their constituent particles.⁹

6. Summary and conclusion

At a given level of granularity (both temporal and spatial) we are confronted with states, processes, and events, and various kinds of temporal dependency amongst them. These all have reality at that level of granularity, notwithstanding the fact that at different granularities they might present a very different appearance, changing their ontological character as they do so. The causal and causal-like temporal dependencies we have described are summarised in Figure 6.

I would like to return to my earlier worries about the role of states in causation. I argued that states cannot be causes, having instead an enabling role (represented in our diagrams by the relation ‘allows’) in relation to actual instances of causation and perpetuation. Here we are talking about a three-way relation involving a state and two events or processes: state S allows event E_1 (or process P_1) to cause (or perpetuate) event E_2 (or process P_2). All these items are concrete particulars (i.e., instances rather than types), either continuants or occurrents, actually standing in the relations stated. What makes this potentially problematic is that the ‘allows’ relation also appears to be able to relate *types*. We can say, for instance, that the door being unlocked allows one to open it by pushing on it, and this makes sense even if no-one does open the door: the statement has a law-like character, covering counterfactual, as well as actual, situations.

This point becomes particularly acute when we turn to *negative* relations such as ‘prevent’, ‘disable’, or ‘disallow’. Clearly prevention cannot be a relation between actual instances of anything: if I say that the signalman’s timely action prevented a train crash,

⁹In [8] it is suggested that merely *continuing to exist* should be regarded as a process enacted by an object.

I am not describing a relation between the action of the signalman and any actual crash, since there *was* no crash. What we can say is that the signalman's action explains the fact that no train crash occurred, all the other conditions at the time being such that, had the signalman's action not occurred, there would have been a crash. With prevention it is clear that we are firmly in the realm of causal explanations, with their invocation of general type-level laws, and are therefore outside the scope of what I have attempted in this paper, which is to provide an ontology of causal and causal-like relations at the instance level. I conclude, provisionally, that an 'allows' relation exists in both realms, whereas the negative counterpart, 'prevents', only exists in the realm of explanation. This is not an entirely satisfactory state of affairs, and the resolution of this difficulty is a topic for further research.

To conclude, the subject of causality is large, and fraught with difficulties. In this paper I have focused on two particular issues which arise when tackling causality from an ontological point of view. They are (1) to elucidate the different roles of states, processes, and events in causation; and (2) to explore not just causation itself but also a cluster of related notions exemplified by verbs such as 'allow', 'perpetuate', and 'prevent'.

I have taken instance-level relations to be primary: the actual causation of one particular occurrence by another is regarded as an ingredient of the world that exists independently of how we describe it and whether we can explain it. It forms part of the "'pushing and shoving' that goes on in the language-independent world" [27, p.151]. But the world also includes *perpetuations*, by which processes may determine other processes, and again these are independently existing ingredients of the world. Both causations and perpetuations are physical transactions, involving the transfer of energy.¹⁰

Other relations we noted are not causal in the same full-blooded sense: the relations of initiation and termination between an event and either a state or a process are not physical transactions but rather, one might say, logical ones. It is a matter of logic that the event of starting to ϕ initiates the state of ϕ ing. Whatever causes the event can be said to result in the state, but something else — a state or process — is needed to perpetuate the state. But these initiations and terminations are again spatio-temporal particulars that can be fitted into the account of the actual world.

Finally, I considered the relations expressed by such verbs as 'allow' and 'prevent', which relate to the preconditions for causal relations to hold. In the case of 'allows', it seems not unreasonable to say that an actual state, answering to a precondition expressed in a general causal law, can be said to bear an instance-level relation to a causation event that would not have been able to occur in the absence of that state. Thus far, 'allows' can be allocated a place in the realm of pure actuality. But its negative counterpart, 'prevents', is clearly absent from that realm; it cannot be seen as a relation between particulars since there is no particular to play the role of 'that which is prevented'. Rather, it forms part of counterfactual reasoning which, by its nature, must handle classes of possible occurrences rather than actual individual occurrences; as such, it is at some remove from our primary concerns in describing what actually goes on.

As a final remark, it might be objected that the examples presented here are, in the words of one of the reviewers, "typical toy examples from philosophical literature", and this raises the question of how well the ontological innovations of this paper would fare when applied to 'industrial scale' examples. I believe that, although not highly complex,

¹⁰In the case of the ball's motion perpetuating itself, this 'transfer' reduces to the limiting case of the ball's maintaining the same energy from one moment to the next.

the examples considered here already encompass the main kinds of causal and causal-like relations that will be needed; but I accept that the theory will need to be tested on a much broader canvas before it can earn its place at the high table of applied ontology.

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