The Conserved Quantity Theory of Causation and Chance Raising

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1. Introduction.

The conserved quantity theory of causation takes causation to obtain between two events when they are linked by a causal process, or a set of causal processes and interactions. However, the theory has problems with cases where an event, which tends to prevent another, fails to do so on a particular occasion, and where those two events are linked by causal processes. Call this the case of "connected non-causes". In fact, I show, this problem is far more widespread than has been realised, and further, the process theory cannot easily be developed to deal with such cases.

It is well known that chance raising accounts of causation easily account for connected non-causes, but face the problem of chance lowering causes, a problem which motivated the conserved quantity theory in the first place. This suggests that the answer is to integrate the two notions. In this paper I show how the conserved quantity theory can incorporate the notion of chance raising so as to solve both of these problems.

2. The Conserved Quantity Theory and the Problem of Connected Non-causes

The conserved quantity theory has been offered in a number of forms (Dowe 1992; 1995; 1998; Salmon 1994; 1997; Skyrms 1980). We will consider just the most recent version formulated by Wesley Salmon

(1997), although the problem to be considered is a problem for all the versions just mentioned. According to Salmon the following three definitions capture the essence of causality:

> Definition 1: A causal interaction is an intersection of world-lines that involves exchange of a conserved quantity,
>
> Definition 2: A causal process is the world-line of an object that transmits a non-zero amount of a conserved quantity at each moment of its history (each spacetime point of its trajectory),
>
> Definition 3: A process transmits a conserved quantity between A and B (A≠B) if and only if it possess [a fixed amount of] this quantity at A and at B and at every stage of the process between A and B without any interactions in the open interval (A,B) that involve an exchange of that particular conserved quantity. (Salmon 1997, sections 2 and 6)

This theory has been refined over recent years in response to various criticisms and problems (see references listed above). However, the conserved quantity theory has problems with ‘connected non-causes’; where an event which tends to prevent another fails to on a particular occasion, and where the two are linked by causal processes. One example is Cartwright’s sprayed plant: a healthy plant is sprayed with a defoliant which kills nine out of ten plants, but this particular plant survives (Cartwright 1983, ch. 1). We can provide a set of causal processes and interactions (characterised by the possession of conserved quantities) linking the spraying and the surviving, yet spraying does *not* cause the plant’s survival. Papineau has given a similar case: being a fat child does not cause one to become a thin adult, although causal processes link the two. As in the sprayed plant case, two events, which we would not call cause and effect, are linked by a set of causal processes and interactions.

According to Papineau these counterexamples show that the process theory of causality is inadequate (1989; 1986).

In fact it can be shown that the failure of the conserved quantity theory at this point is *more* widespread and general than has been recognised. These counterexamples are not esoteric quibbles but a commonplace feature of causation.

Consider a tennis ball bouncing off a brick wall, a paradigm case for the naïve process theory, since it involves clearcut cases of causal processes and their interaction. The passage of the ball through space-time is a causal process by definitions 2 and 3 since it possesses a conserved quantity (momentum) at each instant of its history. The collision between the ball and the wall is a causal interaction by definition 1, since the momentum of the ball changes at the intersection of their worldlines. Now, certainly its hitting the wall is the cause of its rebounding, but the collision with the tennis ball does not cause the wall to remain in the same place, nor does it cause the wall to be still standing. Nor does the collision cause the ball to be green and furry.

For any causal schema involving genuine causal processes and interactions there will be numerous events, facts, or states of affairs which are part of the schema. There is no guarantee that any two such events or facts will stand in a causal relation: in general they will not, although some will. Thus spraying the plant with defoliant does not cause it to survive, nor to still have mostly green leaves, nor to still be in the corner of the yard; while spraying does cause it to be less healthy and to have some slightly yellowed leaves (let’s say).

Indeed, these considerations raise the suspicion that the conserved quantity theory fails to provide a sufficient condition for singular causation in *every* actual schema of processes and interactions. If this is so then the conserved quantity theory is not an adequate account of the way causes and effects are connected.

Can the conserved quantity theory be developed so as to overcome this difficulty? Well, for a start more needs to be said about the events or facts which are linked by causal processes and interactions, and how they are thereby linked.

We shall suppose that the causal relata are either events or facts, both of which concern objects having properties at a time or a time period. An *event* is a change in a property of an object at a time; for example, a quantitative change; or a related simultaneous change in more than one property of more than one object at a time; etc. A *fact* is an object having a property at a time or over a time period. Because both events and facts concern objects, this fits well with the conserved quantity theory. For simplicity let's deal just with facts. Then, presumably, according to the conserved quantity account two facts are connected in a causal relation if and only if there is a continuous line of causal processes and interactions between the objects involved in those facts at those times.

Furthermore, we will take it that such facts or events, if they enter into causation, must involve conserved quantities or supervene on facts and events involving conserved quantities. For example, the fact that the ball is green must supervene on the fact that various bits of the surface of the ball's fur have certain physical properties in virtue of which the ball looks green. If these properties are not conserved quantities, then they in turn must supervene on conserved quantities. This seems to be a natural development of the conserved quantity theory. Then we can write the relevant fact as q(a), which reads 'object a has q amount of conserved quantity q'. If a second type of conserved quantity is involved, we will write this as 'q''.

Then for the most general case of cause and effect we can write the cause as q(a) and the effect as q'(b), where a and b are objects and q and q' are conserved quantities possessed by those objects respectively, at the appropriate times. Then we can take it that:

> Definition 4: There is a causal link between a fact q(a) and a fact q'(b) if and only if there is a thread of facts (or events) between q(a) and q'(b) such that:
>
> (1) at every point on the thread there is an object which possesses a conserved quantity, such that any change of object from a to b and any change of conserved quantity q to q' occur at a causal interaction involving the following changes: Δq(a), Δq(b), Δq'(a), and Δq'(a); and
>
> (2) for any exchange in (1) involving more than one conserved quantity, the changes in quantities are governed by a single law of nature.

The need for (2) is to rule out cases where independent interactions occur by accident at the same time and place.

For example, to take a simple case, the earlier momentum of a billiard ball (q(a) at t_1) is responsible in the circumstances for the later momentum of the same ball (q(a) at t_2). Then the cause-fact and the effect-fact are linked by a single thread involving just the object a and the quantity q, momentum.

As a second example, shown in figure 1, suppose the ball collides with another, so that the earlier momentum of the first ball (q(a) at t_1) is causally responsible for the later momentum of the second ball (q(b) at t_2). Then the cause and the effect are linked by the thread involving firstly q(a), the first ball having a certain momentum; then the interaction Δq(a), Δq(b), the exchange of momentum in the collision, and then q(b), the second ball having a certain momentum. There is a change of object along this thread, but no change in the conserved quantity.

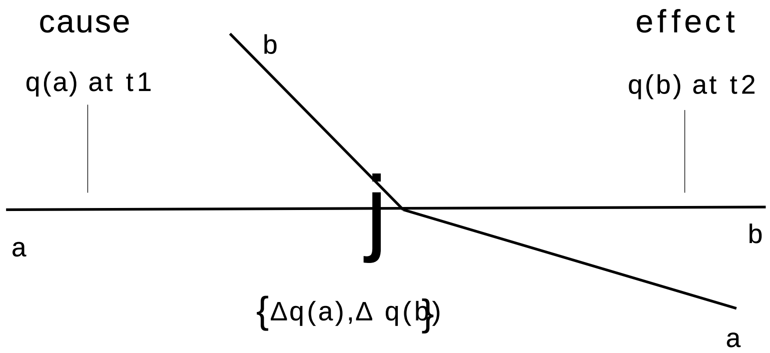

Figure 1: Collision between two balls, a, b. The momentum of the first q(a) is the cause of the momentum of the second q(b).

As a third example, suppose an unstable atom is bombarded by a photon of absorption frequency, which leads to the subsequent decay of the atom (figure 2). Take q to be energy and q' to be charge. Then the cause q(a), the incident photon with certain energy, is linked to the effect q'(c), the existence of the second atom, the product of the decay. It is linked by a thread involving one interaction where there is an exchange of energy, and a new object, and a second interaction where one object becomes another, with an exchange of charge and of energy, which leads to the effect object having a certain charge, in virtue of which it is called the decay product. Further, there are laws governing how energy changes in a such a decay, involving the change in charge that it does.

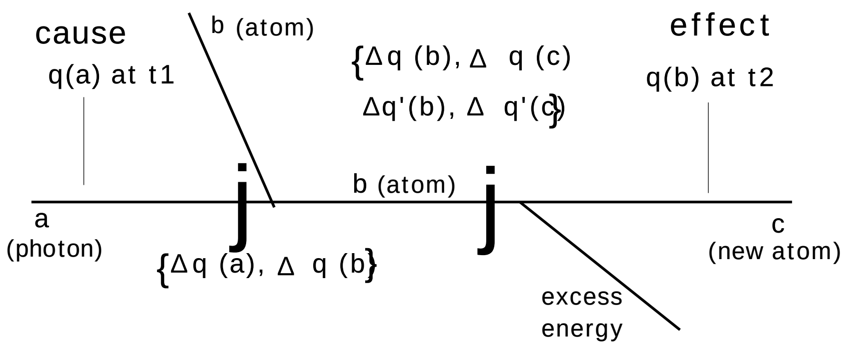

Figure 2: Incident photon a strikes atom b, raises its energy level, which then decays to atom c.

Suppose now, to vary the example, that the atom happens not to decay. Then, by my account, the incident photon is not the cause of the fact that the atom did not decay, since the effect concerns charge, not energy, and there is no interaction where both energy and charge are exchanged.

We can now see how to deal with cases such as the tennis ball's momentum causes it to be green. This is ruled out because there is no appropriate thread involving an object and a conserved quantity. There is the continued existence of the ball and its momentum, but that does not belong to the same thread as the existence of green fur.

This may also solve the sprayed plant case, if for example the cells affected by the poison simply die and the plant's continued life is the result of other independent cells.

However, while it solves many of these sorts of counterexamples, this account cannot completely solve the problem of connected non-causes. (The problem is not just a problem for the conserved quantity theory.) Suppose, to give a fairly abstract example, that some object has quantity q=50, and that a critical value of q for the object is 40 (below which it decays or is dead or something). Suppose an interaction occurs which raises the value of q by 20, then a second interaction occurs which lowers the value of q by 40, leaving it with a q-value of 30, below the critical value. Define the following events (see figure 3):

f_1 — q's value was raised by 20 at t_1

f_2 — q's value was lowered by 30 at t_2

f_3 — q's value was 40 at t_3

f_4 — q's value was less than 50 at t_3

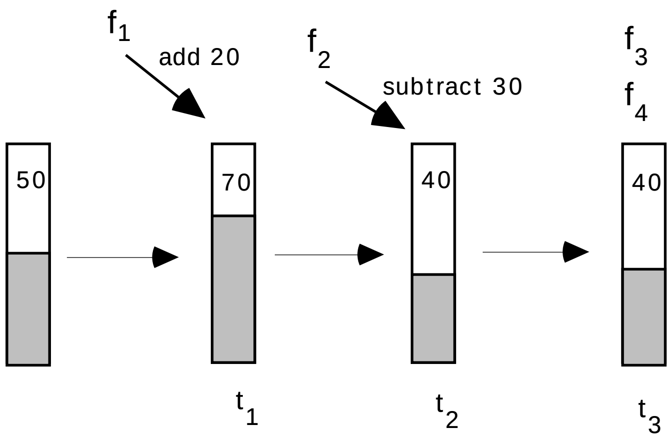

Figure 3

Now, we might be happy to say that f_1 caused f_3, because without f_1 the object would have had a lower value of q (although this would be debatable). But we would not, by any stretch of the imagination, say that f_1 caused f_4. For a start, without f_1 f_4 would have been much more likely. But the problem is, on the embellished conserved quantity account, f_1 *does* cause f_4 because it's the same object and the same quantity involved in both events, connected by a single causal thread. It seems to me that this captures the basic difficulty behind cases such as the sprayed plant and the fat child.

(Another problem which is a problem not only for the conserved quantity theory, but also for other account of causation as well, is that f_1 causes f_3 but not f_4, yet f_3 entails f_4!)

An example of this would be where, in a cold place, the heater is turned on for an hour, bringing the room to a bearable temperature. But an hour later the temperature is unbearable again, say 2^{o} C. Then on my account the fact that the heater was turned on is the cause of the fact that the temperature is unbearable at the later time.

To bite the bullet here would be to accept this implication, that f_1 caused f_4, and insist that whenever two facts are appropriately linked they are causally related. This may have the implication that there is no such thing as unsuccessfully inhibiting something, since a case like the sprayed plant is a case of causal connection. This certainly is counterintuitive, to say the least.

As Cartwright's and Papineau's examples were intended to show, an alternative tradition—namely the probabilistic or chance raising accounts of causation—is able to account for these cases. We now turn to chance raising accounts of causation.

3. Chance Raising Theories and Chance Lowering Causes

One popular approach to causation, the probabilistic or chance raising theory, takes causation to hold between two events only if the occurrence of one event, the cause, makes the probability of the other, the effect, much greater than it would otherwise be[1]. This condition is typically conjoined with others, for example, that the cause occur before the effect, and that there is no third event which "screens off" the relevant relation. We shall consider the probabilistic theory only in so far as it is a theory of singular causation; that is, of the particular relation in virtue of which two particular events or facts are cause and effect.

We note firstly that the chance raising theory easily handles connected non-causes. Being sprayed by defoliant doesn't raise the probability of the plant surviving. Being a fat child doesn't raise the probability of being a thin adult. The tennis ball hitting the wall doesn't raise the probability of the wall staying standing in the same place, or of the ball being green and furry.

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1 In philosophy this sort of theory is usually attributed to Suppes' influential book *A Probabilistic Theory of Causality*, (1970), (see also Suppes 1984, ch. 3), although both Reichenbach and Good had offered earlier versions (Good 1961; 1962; Reichenbach 1956). A statistically sophisticated version of the probabilistic theory has been given by Glymour and co-workers (Glymour and others 1982). Also see (Cartwright 1983; Eells 1991; Lewis 1986; Mellor 1995).

However, one persistent argument against the probabilistic or chance raising theory concerns counterexamples where a particular causal chain contains elements which lower the chance of their effect[2]. One example is the case where a golf ball is rolling towards the cup, but is kicked by a squirrel, and then after a series of unlikely collisions with nearby trees, ends up rolling into the cup (Eells and Sober 1983). This is a case, it is argued, where a singular cause lowers the probability of its effect, in other words, a counterexample to the claim that the probabilistic theory provides a necessary condition for singular causation.

There are a range of ways to handle cases like these[3]. However, these methods cannot handle certain cases involving the kind of genuine single case objective chance found in quantum mechanics. Consider the following example (see Figure 4), which, according to our best physical theories, involves genuine indeterminism.

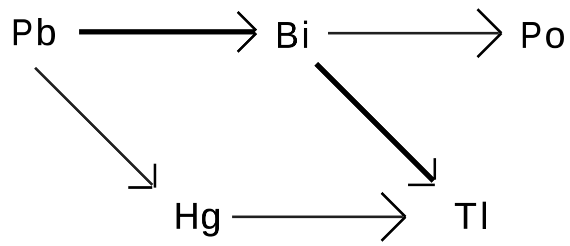

Figure 4 Chance-lowering Decay Scheme.

An unstable atom Pb^{210} may decay by various paths as shown in Figure 4, which depicts the complete range of physical possibilities for this atom. Pb^{210} may decay to either Po^{210} or to Tl^{206}, in each case by a two step process. When Pb^{210} decays, the probability that it will produce Hg^{206} is 1.8

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2 The major point of dispute between Salmon (1984, ch. 7)and Suppes (1984, ch. 3), Such counterexamples are variations on an example due to Rosen (1978).

3 Salmon has outlined a number of methods used to solve this type of problem (1984, ch. 7). See also the work by Glymour and co-workers eg (1982). Another kind of strategy is the ‘despite defence’ suggested by Suppes (1984, p. 67) and defended by Papineau (1989; 1986), Eells (1988, p. 130) and Mellor (1995, pp. 67-8). I have addressed this in length elsewhere (Dowe and others 1996; Dowe 1993) and so will not consider it here.

x 10^{-8}. The probability that Hg^{206} will produce Tl^{206} is one. When Bi^{210} decays, the probability that it will produce Tl^{206} is 5.0 x 10^{-7} (from Enge 1966, p. 225, via Dowe 1993[4]). We assume that each unstable atom has a very short half-life relative to the time frame under consideration.

Let C be the decay to Bi; D the decay to Hg; E the production of Tl; F the production of Po. Note that these events are not time-indexed. Then,

$$P(E) = P(C)P(E \mid C) + P(D)P(E \mid D)$$

$$= [(1 - 1.8 \text{ x } 10\text{-}8) \text{ x } 5.0 \text{ x } 10\text{-}7] + (1.8 \text{ x } 10\text{-}8 \text{ x } 1)$$

$$= 5.18 \text{ x } 10^{-7}$$

and $\qquad P(E \mid C) = 5.0 \text{ x } 10^{-7}$

Thus C lowers the chance of E.

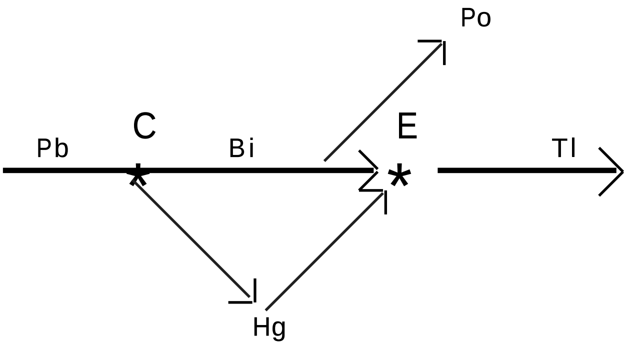

Figure 5

Take a particular instance (figure 5) where the process moves: Pb^{210} ’ Bi^{210} ’ Tl^{206}, ie C occurs and leads to E. Then we should say that C causes E, yet it lowers its chance.

Classic versions of chance raising theory, such as Suppes 1970, fail to account for this case. Suppes requires that $P(E \mid C) > P(E)$ unless there is some other factor which screens off this dependence. In our case there isn't, since it is genuinely indeterministic (Dowe 1993; Salmon 1984).

4 In turn a variant of a case presented by Salmon (1984, pp. 200-1). See also (Dowe and others 1996).

One influential variation of the chance raising theory is the probablistic dependence theory of David Lewis (1986, pp. 175-8), which replaces the usual probabilistic relation with counterfactual conditionals about chance of the form 'if event C were to occur, the chance of event E would be much greater than if C were not to occur.' Lewis calls this relation 'probabilistic dependence'. Lewis' theory has a number of advantages over the usual probabilistic theory; however it too fails to account for the decay case. For if C were *not* to occur, that is, if the decay Pb—> Bi were not to occur, then E would be more likely than if C did occur, because C's not occurring leaves a state of affairs such that Pb atom has not decayed, but will soon, ensuring that D occurs and subsequently, with probability 1, that E occurs.

A recent version of this is that of Mellor (1995) according to which for C to cause E the chance that C gives E must be greater than the chance that not C gives E,

$$ch_C(E) > ch_{\sim C}(E).$$

where the value of $ch_{\sim C}(E)$ is given by the closest world conditional ~C ch(E) = p; and the chances are understood as single case objective chance. However, this also fails in the decay case, since $ch_C(E) = 5.0 \times 10^{-7}$, while ch(E) at closest ~C-worlds is 5.18×10^{-7}.

However the conserved quantity theory provides a ready answer to this kind of counterexample. Take the squirrel case, where a golfball is travelling towards the hole, but a squirrel kicks the ball away, but (improbably) the ball hits a tree and goes in. There is a single thread of causal processes and interactions, all involving the ball, which can be traced from the squirrel's kick to the ball's landing in the hole. The kick is a genuine causal interaction, and so is the collision with the tree (both are changes in the momentum of the ball).

The same may be said for the decay case. An atom is a genuine causal process and its decay is a genuine causal interaction involving, as it happens, not only production of the atom Tl, but also either an alpha particle or a beta particle. Both C and E, in our particular case, involve a change in charge, a conserved quantity. As we have seen, for the conserved quantity theory it is not of crucial importance that the cause raises the probability of the effect, but rather that there is a set of continuous causal processes and interactions linking the two events. Thus the conserved quantity theory accounts easily for these counterexamples. Not surprisingly, then, this has been one of the major arguments in its favour[5].

So we have two theories and two problems. The probabilistic theory cannot handle the chance lowering causes, but easily handles the connected non-causes. The process theory easily handles the chance lowering cases, but cannot handle the connected non-causes. This suggests an approach which incorporates both of these insights. In the next section we offer just such an approach.

4. Integrating Solutions and the Mixed Double Effects

Some authors (Sober 1985 was perhaps the first) have pointed to an asymmetry between the case of the squirrel and the case of the sprayed plant. The asymmetry is that while both have the same probabilistic structure, with the particular events occurring contrary to the governing statistical relations, yet the squirrel's kick is a cause and the spraying of the plant is not. The same asymmetry exists between the decay case (similar to the squirrel) and the tennis ball case (similar to the sprayed plant). Some authors have used an explanation of this asymmetry as the basis for an account which brings together both the chance raising insight and the process insight. I call such a synthesis an "integrating solution". Authors who have attempted such a synthesis include Eells, Lewis and Menzies.

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5 For example, Dowe and others 1996; Dowe 1993; Salmon 1984, ch. 7.

In *Probabilistic Causality* (Eells 1991, ch. 6; see also Eells 1988), Ellery Eells suggests that the difference between cases like the decay case and the sprayed plant is due to different ways that the probability of an effect evolves between the occurrence of the two events. C causes E just if P(E) changes at the time of C, and just after C is high, and higher than it was just before C; and remains high until the time of E (Eells 1988, p. 120). This gives the right result for cases like the sprayed plant, but it does not solve the decay counterexample. The particular instance where the decay process moves from Pb –> Bi –> Tl gives a trajectory for P(E) which drops at C *and remains lower*, yet we call C a cause of E. More specifically, the probability trajectory develops as follows: up until and immediately before C the probability of E is 5.18×10^{-7}, and from C until immediately before E the probability of E is 5.0×10^{-7} (Dowe 1996, pp. 230-231).

A more promising approach is due to Lewis and Menzies. Lewis (1986, pp. 175-184), defines a 'chain of probabilistic dependences' (in Menzies' wording, (1989, p. 650) as an ordered sequence of events such that each event probabilistically depends on the previous event. I call this a 'Lewis-chain' (Dowe 1996, p. 232). Then C is a cause of E if and only if there is a Lewis-chain between C and E.

According to Menzies (1989) there is an *unbroken causal process* between events C and E if and only if for any finite sequence of times between C and E, there is a corresponding sequence of events which constitutes a Lewis chain (of probabilistic dependences), and C is a cause of E if and only if there is a chain of unbroken causal processes between C and E. I call this the 'Menzies-chain' (Dowe 1996, p. 232). The effect of this is to allow one to cut the chain at convenient places.

These accounts are able to handle the decay case as set out above. Take the event C', the existence of the Bi atom at a time between the occurences of C and E. There is a relation of probabilistic dependence between C and C' because if C were not to occur then C' would not occur, except in the unlikely scenario that a Bi atom is produced by a process other than the decay of that Pb atom. Thus if C were not to occur, C' would be very much less likely than if C were to occur. There is also a relation of probabilistic dependence between C' and E because if C' were not to occur then E would almost certainly not occur. (This follows from the Lewis approach to interpreting these counterfactuals: in supposing C' not to occur, we hold fixed the world up until the time of C', which means that C occurred (and so the decay to Hg will not), and that the atom Bi has disappeared; so there's virtually no chance that E will occur.) Thus there is a Lewis chain linking the cause and the effect, comprising of C-C'-E. There is also a Menzies chain. For any time t_i between the times of C and E one can define the event C_i, the existence of the Bi atom at time t_i, such that C-C_i-E forms a Menzies chain (Dowe 1996, p. 232).

However, these theories are not successful with a simple hypothetical variation on the decay case (Dowe 1996, pp. 232-233) where we have a *cascade*, where the Bi atom immediately decays to Tl (supposing that time is discrete, and that the decay of Bi to Tl occurs at the very next instant following the decay of Pb to Bi). Then there is no time between the times of C and E, and so there is no event C', and since C and E do not stand in the relation of probabilistic dependence, there is no Lewis chain between the cause and the effect. And by similar reasoning, there is no Menzies chain between the cause and the effect.

This counterexample brings out the fact that there is something ad hoc about the solution. It shouldn't matter how dense the process is linking cause and effect.

So these attempts to incorporate the idea of a process into a chance raising theory seem to fail to account for the decay case. However, I think that an alternative approach can succeed where these fail.

The chance lowering decay is an example of a “mixed double effect”. In general, an event C initiates two processes, one of which has a chance of causing E, the other a chance of preventing E.

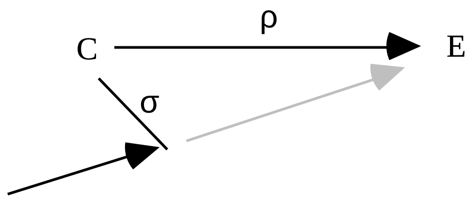

Figure 6: Decay case as a “mixed double effect”

This formulation might seem a little awkward. The first is that, in the decay case, C does not strictly speaking initiate a process which might have prevented E. Rather, simply by occuring, it prevented the reliable process Pb-Hg-Tl producing E; and had E not occurred, C would have been a preventer of E. Secondly, it is admittedly odd to speak of a preventing as being a process, since there is no process linking C and E’s non-occurrence (see Dowe, 1998). However, these points aside, it will be convenient to speak of the two processes C initiates.

Events with mixed double effects act at the same time to cause and to prevent some event. Of course they cannot successfully do both, although they could fail to do both.

Depending on the actual probabilities involved, there are two problems with mixed double effects. Firstly, if $P(E \mid C) < P(E)$ and process ρ is successful, then C causes E and we have a chance lowering cause. Secondly, if $P(E \mid C) > P(E)$ and process σ is successful, then C prevents E and we have a chance raising prevention.

Had there been just the one process, ρ say, then it would have been the case that C caused E and raised its chance. Had there been just process σ then it would have been the case that C prevented E and lowered its chance. These are unproblematic cases. The problems arise, we can now see, when an event C is both potentially a cause and potentially a preventer- the mixed double effect. The decay case is such a case.

I think there is a way to combine the process and the chance raising insights so as to account for the mixed double effect. To begin, consider Mellor's concept of the chance that C gives E in the circumstances, which he writes as "$ch_C(E)$". In cases such as the mixed double effect we can (although Mellor doesn't) think of that chance as having components. Just as the gravitational force on the moon has a component due to the earth and a component due to the sun, so the chance that C gives E has a component due to the possibility of process ρ and a component due to the possibility of process σ.

In the decay case (figure 5), C gives E a chance of 5.0×10^{-7}, which has as components the chance 5.0×10^{-7} that E will be produced via Bi decay, and the chance zero that E will be produced via Hg decay. We can write this as:

$$ch_{C\rho}(E) = 5.0 \times 10\text{-}7$$

$$ch_{C\sigma}(E) = 0$$

where $ch_{C\rho}(E)$ reads "the chance that C gives E in virtue of ρ".

My suggestion is, then, that for C to be the cause of E in virtue of process ρ, then C must raise the chance of E were ρ the only process involved between C and E. Whether C raises the chance of E at that world is itself a counterfactual matter, analysed in the usual closest world manner.

This is not a counterfactual that can be analysed in the usual manner of Lewis, because process ρ begins, temporally, with C. What we need to do is compare the ch(E) at the closest worlds to ours where ρ is the only process involved between C and E, with the ch(E) at the closest worlds to that world where C does not occur. The ch(E) at the closest worlds to ours where ρ is the only process involved between C and E should be the component $ch_{C\rho}(E) = 5.0 \times 10^{-7}$, whereas the ch(E) at the closest worlds to that world where C does not occur is $ch_{\sim C\rho}(E)$, which in our decay example is zero, since C is a necessary cause of E. Thus

$$ch_{C\rho}(E) > ch_{\sim C\rho}(E),$$

so C is a cause of E in virtue of process ρ.

Similarly, for C to be the preventer of E in virtue of process σ, then C must lower the chance of E were σ the only process involved between C and E. In our case $ch_{C\sigma}(E)$ is zero, while $ch_{\sim C\sigma}(E)$ is one, since if C doesn't occur D occurs, which leads to E with probability 1.

This approach may seem teleological, in that it analyses chances in terms of future possibilities, but I cannot see any other way forward. In some cases of mixed double effect we could conditionalise on different parts of C, if, for example, the atom's having of one quantity is responsible for one process and its having another quantity is responsible for the other (in the manner of a well-known solution to some apparently chance lowering causes- see Salmon 1984, ch 7). But in general it may be the same quantity responsible for and involved in both processes. In our case this is the case. Further, there is no way to conditionalise on unknown parts of C because we already have all the information there is, if the indeterministic interpretation of quantum mechanics is correct.

So the analysis of causation that I am proposing is as follows:

C causes E iff

(1) there is a causal link ρ between C and E, and

(2) $ch_{C\rho}(E) > ch_{\sim C\rho}(E)$.

Causal links are defined as in definition 4, above.

To recap, this account solves the problem of the sprayed plant by introducing to the conserved quantity theory a chance raising condition. But it avoids the problems with chance lowering causes by distinguishing components of objective single case chance, delineated according to relevant possible processes. These processes are themselves delineated by the original conserved quantity theory (definitions 1-3).

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