



Causes as Probability Raisers of Processes

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The Journal of Philosophy, Vol. 98, No. 2. (Feb., 2001), pp. 75-92.

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CAUSES AS PROBABILITY RAISERS OF PROCESSES*

Causation, according to David Hume, is one of the three fundamental conceptual relations (along with resemblance and contiguity), and is the foundation of all reasoning concerning matters of fact. Causation, according to various contemporary philosophers, is required for the analysis of metaphysical concepts such as persistence, scientific concepts such as explanation and disposition, epistemic concepts such as perception and warrant, ethical concepts such as action and responsibility, legal concepts such as homicide and negligence, mental concepts such as functional role and conceptual content, and linguistic concepts such as reference, to name just a salient few. Yet the nature of the causal relation itself remains mysterious.

The leading accounts of the nature of causation divide into *probability-raising* and *process-linkage* views. On the probability-raising view, causation is rooted in the comparative probability of the effect with the cause versus without. On the process-linkage view, causation is rooted in the existence of a connecting line from cause to effect. I propose a third alternative which synthesizes these views while solving their problem cases. On this alternative, causation is rooted in the comparative probability of the connecting line to the effect with the cause versus without: causes as probability raisers of processes.

In the first two sections, I (briefly) outline the probability-raising and process-linkage views and identify a space of problems, and then I focus on developing the alternative probability-raisers-of-processes solution. I identify problems for this view as well, though I conclude that it is at least in important respects a step forward.

I. PROBABILITY-RAISING AND PROCESS-LINKAGE VIEWS

The probability-raising view of causation has its roots in the social sciences and in the philosophical analysis of causation in terms of necessary and/or sufficient *conditions*. In the social sciences, issues concerning causation are addressed by the use of algorithms that seek covariations in frequency data, and then sort the causal covariations

* Thanks to David Coady, Cian Dorr, Harty Field, Ned Hall, Chris Hitchcock, Barry Loewer, Tim Maudlin, Michael McDermott, Brian McLaughlin, Ram Neta, L. A. Paul, and especially to David Lewis.

from the merely correlational ones.¹ Many social scientists have operationally identified the causal relation with these algorithms. This is a statistical conception of causation.

The probability-raising view also represents the indeterminism-induced synthesis of philosophical accounts of causes in terms of necessary and/or sufficient conditions for their effects. The natural extension of the necessary condition view into the indeterministic case is that causes are necessary, not for the presence of their effects (since the effect might still retain some nonzero chance of spontaneous eruption even without the cause), but for a higher probability of their effects. Thus, for David Lewis,² causation is rooted in the counterfactual claim that, had the cause not occurred, then the chance of the effect would have been less; and D. H. Mellor³ requires that $\text{Ch}_C(E) > \text{Ch}_{\neg C}(E)$, which measures the chance that the actual circumstances give E versus the counterfactual chance that the circumstances minimally changed with respect to C would give E . The natural extension of the sufficient condition view into the indeterministic case is that causes are sufficient, not for the presence of their effects (since the effect might still retain some nonzero chance of fizzling even with the cause), but for a higher probability of their effects. Thus, for Patrick Suppes,⁴ causation is rooted in the statistical claim that the limiting frequency of effect-type events is greater with cause-type events than without: $p(E|C) > p(E|\neg C)$; and Ellery Eells⁵ requires that the chance of E increase to a high value just after the time of C and remain high until the time of E . And so counterfactual dependence flows into counterfactual chance dependence, constant conjunction flows into comparatively frequent conjunction, and the two merge into the wider seas of probability raising.

The process-linkage view of causation has its roots in physics and in the philosophical analysis of causation in terms of physical connections rather than abstract conditions. Physicists have long suggested that flows of energy momentum, or something of that sort, are the basis for actual causal connections.⁶ Many philosophers have rejected

¹ Peter Spirtes, Clark Glymour, and Richard Scheines offer a sophisticated algorithmic approach in their *Causation, Prediction, and Search* (New York: Springer, 1993).

² "Causation," in *Philosophical Papers*, Volume II (New York: Oxford, 1986), pp. 172-213.

³ *The Facts of Causation* (New York: Routledge, 1995).

⁴ *A Probabilistic Theory of Causality* (Amsterdam: North Holland, 1970).

⁵ *Probabilistic Causality* (New York: Cambridge, 1991).

⁶ Władysław Krajewski—"Energetic, Informational, and Triggering Causes," *Erkenntnis*, XLVII (1997): 193-202—traces energy flow accounts of causation back to Robert Mayer (the discoverer of the law of conservation of energy) in 1842.

the necessary and/or sufficient conditions approach to causation in favor of physical connections. David Fair⁷ identifies actual causation with energy flow; Wesley Salmon⁸ describes causal processes as those connections capable of propagating their own structure (transmitting a mark); and Douglas Ehring⁹ requires the persistence of a trope from cause to effect. Think of the path of energy flow, the wave of structural propagation, and the worldline of the persisting trope as constituting a physical connecting line from cause to effect.

I propose to separate the questions of how the probability-raising and process-linkage relations are best analyzed (which I have discussed at length elsewhere), from the question (which I focus on here) of how the causal relation should then be analyzed. In the remainder of this section, I sketch my preferred analyses of probability raising and process linkage, and in what follows I focus on the analysis of causation.

Probability raising is best analyzed, I think, in terms of Lewis's counterfactual chances, on which C is a probability raiser of E if and only if (i) C and E are actual distinct events, (ii) $\text{ch}(E)\text{-at-}t_C = p$, and (iii) $\neg C \square \rightarrow \text{ch}(E)\text{-at-}t_{\neg C} < p$. In saying that C and E are actual distinct events, I mean that each is a \langle Property, Region \rangle ordered pair whose first member is actually instantiated at its second, with the C and E properties logically independent and the C and E regions spatiotemporally disjoint. In saying that $\text{ch}(E)\text{-at-}t_C = p$, I mean that the propensity (objective single-case chance) of E in the circumstances at the time of C is p . In saying that $\neg C \square \rightarrow \text{ch}(E)\text{-at-}t_{\neg C} < p$, I mean that the counterfactual supposition of the nonoccurrence of C entails that the propensity of E in those same circumstances with C deleted would have been less than p .¹⁰

Process linkage is best analyzed, I submit, in terms of pairwise nomic subsumptions: processes are lawful sequences.¹¹ Not just any

⁷ "Causation and the Flow of Energy," *Erkenntnis*, XLVIII (1979): 219-50.

⁸ *Scientific Explanation and the Causal Structure of the World* (Princeton: University Press, 1984). In his *Causality and Explanation* (New York: Oxford, 1998), Salmon responds to a suggestion from Phil Dowe (for whom causal processes are the worldlines of conserved-quantity-bearing objects—"Wesley Salmon's Process Theory of Causality and the Conserved Quantity Theory," *Philosophy of Science*, LIX (1992): 195-216), by moving to a conserved-quantity transmission view of causal processes. This remains squarely within the process-linkage camp.

⁹ *Causation and Persistence* (New York: Oxford, 1997).

¹⁰ For further discussion, see Lewis as well as Mellor.

¹¹ David Armstrong proposes: "A law (an entity in the world) provides the ground in nature for an inference. The cause is like the antecedent"—"The Open Door: Counterfactual versus Singularist Theories of Causation," in H. Sankey, ed., *Causation and Laws of Nature* (Boston: Kluwer, 1999), pp. 175-85, here pp. 183-84.

lawful sequence will do. The antecedent must be prior to the consequent, and the lawful connection must not be revealed to be merely correlational by a more fundamental law. More precisely, C is *directly* process linked to E if and only if (i) C and E are actual distinct events, (ii) there is a law L of the form $(\forall R) (\forall R') (\langle P, R \rangle \square \langle P', R' \rangle)$ such that C is an instance of the antecedent and E of the consequent, (iii) there is no law L' more fundamental than L such that actual prior event A is an instance of the antecedent and $C \& E$ is an instance of the consequent, and (iv) $t_C < t_E$. In speaking of laws as having the form $(\forall R) (\forall R') (\langle P, R \rangle \square \langle P', R' \rangle)$, I take the quantifiers to range over regions, and the laws to relate the properties of one region to those of another. Thus events, understood as $\langle P, R \rangle$ pairs, can instantiate the antecedents and consequents of laws. Process linkage in general is then defined from the direct case: C is process linked to E if and only if there is a chain of direct process links between C and E .¹²

So when a brick is thrown through a window, on the lawful sequence analysis of *process*, there is a sequence of events from the throwing of the brick, through its intermediary trajectories, to the shattering of the window; and the events in this sequence will be pairwise lawfully related (and not merely covariants, and rightly temporized). The initial conditions of the brick being *here* with a certain momentum at t_0 will lawfully entail that the brick flies to *there* at t_1 . And since energy flows are a this-worldly instance of lawful evolution, the lawful subsumption analysis both undergirds the idea of, and inherits the plausibility of, Fair's empirical identification of processes with energy flows.

I claim that however the probability-raising and process-linkage relations are interpreted, causation cannot be understood by probability raising or process linkage alone, but rather should be understood by a synthesis of these relations on which causes are probability raisers of processes. Since the discussion that follows is relatively independent of any specific understanding of probability raising and process linkage,¹³ for the sake of generality, I speak of 'probability raising' and 'process linkage' without further interpretation (unless otherwise indicated). The reader is invited, though not required, to understand these notions as I do.

¹² For more details, see my "Processes as Lawful Sequences" (unpublished).

¹³ I do assume that: (i) both the probability-raising and process-linkage relations are asymmetric, (ii) the probability-raising relation is circumstance sensitive, and (iii) the process-linkage relation extends to worlds with different laws than ours (and so is not tied into any contingent details of actual physics).

Supposing we have some notion of probability raising and some notion of process linkage in hand, how (if at all) can causation be analyzed?

II. THE PROBLEM SPACE

Causation cannot be analyzed purely in terms of probability raising or purely in terms of process linkage, however these notions are interpreted and however they are refined. There are counterexamples to these approaches which extend to even their most sophisticated refinements. These counterexamples interlock to form a problem space that no extant account of causation can navigate.

(1) Causation without probability raising (*preemption*, and its *trumping* variant): Pam throws a brick through the window. Meanwhile, Bob (a more reliable vandal), holds his throw on seeing Pam in action, though had Pam not thrown Bob would have:¹⁴

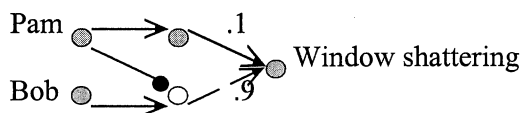


DIAGRAM 1

Preempting Pam's throw is obviously a cause of the window shattering. But her throw is a probability lowerer of the shattering: since Bob is a more reliable vandal, the window's chances would have been worse with Bob in action. Thus probability raising is not necessary for causation.¹⁵

Probability-raising theorists are well aware of preemption and have responded with an extensive literature of refinements. These refinements divide into two general strategies: *factor intermediaries* and/or *require precision*: intermediary-based approaches look to

¹⁴ Diagram conventions: filled circles doubly represent neurons that fire and events that occur, unfilled circles doubly represent neurons that do not fire and events that do not occur, arrows represent stimulatory connections, dots inhibitory connections, and numbers probabilistic connections of varying strengths. If two neurons are connected by a nonprobabilistic stimulatory connection and the first fires, the second will fire unless inhibited.

¹⁵ For further discussion of these cases, see Lewis; I. J. Good, "A Causal Calculus I," *British Journal for the Philosophy of Science*, xi (1961): 305-18; and Peter Menzies, "Probabilistic Causation and Causal Processes: A Critique of Lewis," *Philosophy of Science*, lvi (1989): 642-63.

intermediary events or probability evolutions to try to find a chain of causations from preemptor to effect, and precision-based approaches look to the exact time and manner of the events involved to try to find differences in the effect attributable to the preemptor.¹⁶

There are, however, variants of preemption (*trumping*) with no intermediaries to factor or differences to be precise about, which immediately undercut all extant probability-raising-based strategies against preemption.

The silver-tongued sergeant and mumbling major both order 'Charge!' and so the corporal decides to charge. The major's order is a cause of the corporal's decision, as can be seen from the fact that ranking orders trump: when orders conflict the corporal will follow the major, so when they accidentally converge the same should hold. But the major's order is a probability lowerer of the corporal's decision: the probability of the corporal deciding to charge in those circumstances would have been greater had the major left it to the silver-tongued sergeant to give the order since the major is more likely to be misheard.¹⁷

It is an empirically open question (concerning exactly how the mind works) whether there are any relevant intermediaries between order and decision, and/or any precisifiable differences in the decision attributable to the major: certainly, the corporal need not be conscious of either. And so it is possible to have preemption

¹⁶ Examples of intermediary-based approaches include Lewis's original approach which takes the transitive closure of probability-raising, Menzies's requirement of temporally continuous chains of probability raisings, Eells's use of probability trajectories through the (*C*, *E*) temporal interval, and Igal Kvart's constructions based on further conditionalization on temporally intermediate events. These intermediary-based approaches are offered, respectively, in Lewis; Menzies; Eells; and Kvart, "Cause and Some Positive Causal Impact," in J. Tomberlin, ed., *Philosophical Perspectives 11: Mind, Causation, and World* (Cambridge: Blackwell, 1997), pp. 401-32.

Examples of precision-based approaches include: Lewis's fragility proposal on which probability raising is assessed with *C* and *E* required to have their exact actual times and manners; L. A. Paul's time-tracking emendment on which *C*'s being a probability raiser of *E* is disjoined with *C*'s being a probability raiser of *E*-at-*t*; and Deborah Rosen's suggestion that probability raisings that disappear under precisification are spurious. These precision-based approaches are offered, respectively, in Lewis; Paul, "Keeping Track of the Time: Emending the Counterfactual Analysis of Causation," *Analysis*, LVIII (1999): 191-98; and Rosen, "Discussion: In Defense of a Probabilistic Theory of Causality," *Philosophy of Science*, XLV (1978): 604-13.

¹⁷ The probabilistic impact buttresses the causal claim, since the chance of the corporal deciding to charge is keyed into the chance of him correctly understanding the major's mumbling (and is independent of the chance of him grasping the sergeant's order).

without intermediaries to factor or differences to be precise about.¹⁸

(2) Probability raising without causation (*fizzling*, and its *overlapping* variant): Fred grabs a brick and aims. Pam, oblivious to Fred, throws a brick through the window. Perhaps she preempts Fred, or perhaps Fred quits on his own, or perhaps he throws but wide. Suppose that at the time Fred aimed there was some non-one chance of Pam succeeding and some nonzero chance of Fred succeeding without Pam. (The preemption diagram above represents just such a case, with Bob as the fuzzer.)

Fizzled Fred's aiming is obviously not a cause of the window shattering. But his aiming is a probability raiser of the shattering, given Pam's non-one and Fred's nonzero chance of success at the time: when Fred aimed the window's prospects were worse. Thus probability raising is not sufficient for causation.¹⁹

Probability-raising theorists have only recently become aware of fizzlings, but the same general strategies of factoring intermediaries and/or requiring precision suggest themselves. There are, however (as with preemption), variants of fizzling (*overlapping*) with no intermediaries to factor or differences to be precise about.

Suppose that an atom of U238 and of Ra226 are placed in a box at t_0 , and that at t_1 there is an atom of Th234, an alpha particle, and (still) an atom of Ra226 in the box. The presence of the radium at t_0 is not a cause of the presence of an alpha particle at t_1 . Since Ra226 decays into Rn222 plus an alpha particle, it is evident from the absence of Rn222 (and the continuing presence of the Ra226) that the alpha particle was not produced by radium decay, but rather by the independent process of uranium decay in which U238 decays into Th234 plus an alpha particle. But the presence of the radium is a probability raiser for there being an alpha particle, as follows from the lawful probability λ' of radium decay:

Since particle emissions from radioactive sources (as standardly understood) occur spontaneously and directly, there will be no hidden intermediaries to factor, and if at least one of the particles is in a superposition of location so that the two are "smeared" over a common region, then there can be no differences at all in the alpha

¹⁸ For a full discussion of these cases, see my "Trumping Preemption," this JOURNAL, xcvi, 4 (April 2000): 165-81.

¹⁹ For more on these cases, see Menzies; and Christopher Read Hitchcock, "Do All and Only Causes Raise the Probabilities of Effects?" (unpublished).

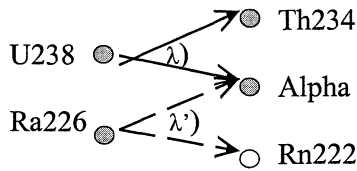


DIAGRAM 2

emission projected from either source. So no manner of factoring intermediaries and/or requiring precision will help. Thus probability raising, even when refined to factor intermediaries and/or require precision, is not sufficient for causation.²⁰

So far, it seems as if the causal relation tracks the process-linkage relation rather than the probability-raising relation. The preempting cause is connected to the effect and the fizzled noncause is not (just look at the diagrams!). But there are also cases where the causal relation looks to track the probability-raising relation rather than the process-linkage relation.

(3) Causation without process linkage (*disconnections*): the plane is on a collision course with the mountain. The air traffic controller is about to alert the pilot to turn, when the saboteur destroys the radio tower, and so the alert is not transmitted, and so the plane crashes.

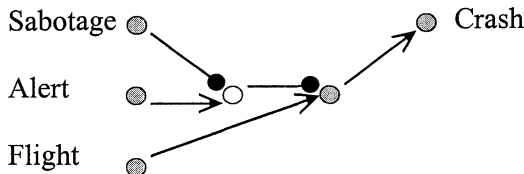


DIAGRAM 3

The sabotaging is obviously a cause of the crash, which intuition may be buttressed by the following considerations. Statistically, sabotages in these circumstances will be universally followed by crashes. Counterfactually, had the tower not been sabotaged then the crash would not have occurred. The explanation for why the plane crashed will surely include the sabotage. Knowing that the sabotage occurred

²⁰ For further discussion, see my "Overlappings: Probability-Raising without Causation," *Australasian Journal of Philosophy*, LXXVIII (2000): 40-46.

will license an inference to the crash. Sabotages in these circumstances are an effective means for crash-hungry agents. The saboteur will be held morally responsible for the crash. In short, all the connotations of causation are in full force.

But as the diagram suggests, no process links sabotage to crash. No relevant energy-line/structure/trope or whatnot persists between them, and no lawful sequence links them. Rather, what is salient here is the *absence* of a process. If only there had been an alert transmitting process connecting tower to pilot, the crash might well have been prevented, but the sabotage prevented that.²¹

Process-linkage theorists appear to be largely unaware of these cases, or at least unaware of how ubiquitous and paradigmatically causal they are. Some process-linkage theorists have (for independent reasons) refined their semantics by *covering absences* and/or *conjoining probability raising*: absence covering approaches add counterfactuals about processes to cover the case of cause and/or effect being an absence ($\neg C/\neg E$), and probability-raising conjunctions require process linkage and probability raising.²² But covering absences will not help since the disconnecter and effect are both presences, and conjoining probability raising (or anything else) will not help since we already have causation without process linkage. Thus process linkage, even when refined to cover absences and/or to require probability raising, is not necessary for causation.

(4) Process linkage without causation (*traces*): Pam throws the brick through the window while innocent Tom watches in dismay, or eats a sandwich, or contemplates fate. Obviously, there is no causation

²¹ Disconnections are present in even the most paradigmatic causal sequences. Gus gets mad (C), pulls the trigger (D_1), fires a bullet through Vic's heart (D_2), and Vic dies (E). Here is causation if anything is. But if one examines how muscles contract, how guns fire, and how heart injuries kill, one will find disconnections at every step. For instance, heart injuries kill not by a connecting process, but rather by disconnecting what would otherwise have been a process, namely, the pumping of oxygenated blood to the brain. For further discussion, see Ned Hall, "Two Concepts of Causation" (unpublished); Lewis, "Void and Object" (preprinted by the Department of Philosophy, University of Melbourne, 1998); and my "Causation by Disconnection" (forthcoming in *Philosophy of Science*).

²² Fair and Dowe both offer absence-covering extensions (although Dowe relegates the extension to the ersatz status of "causation*"), and Ehring as well as Hector-Neri Castañeda both conjoin the process-linkage and probability-raising approaches. These refinements appear, respectively, in Fair; Dowe, *Physical Causation* (unpublished); Ehring; and Castañeda, "Causes, Causity, and Energy," in Peter French, Thomas Uehling, Jr., and Howard Wettstein, eds., *Midwest Studies in Philosophy, Volume IX: Causation and Causal Theories* (Minneapolis: Minnesota UP, 1984), pp. 17-28.

from Tom's watching or whatever else to the window shattering: if ever there is a lack of causation, it is here. But there are presumably lots of processes connecting Tom to the shattering. Photons and sound waves and dust motes and other *mere traces* of Tom's watching connect these events.

The obvious thing to say about traces is that they are *irrelevant* connections. But relevance constraints (which counterfactuals express so naturally) are just what the process-linkage semantics foregoes.²³

Covering absences clearly will not help since *C* and *E* are presences here. Conjoining probability raising will help (assuming the probability-raising relation in use does not require complete precision), but at the cost of newfound failure in preemption cases since, as shown above, preemptions involve causation without probability raising. And conjoining probability raising will not even secure sufficiency if the trace comes from a fizzler: fizzled Fred's aiming is *both* a probability raiser of the window shattering *and* (presumably) connected to the shattering by various stray photons, but is still not a cause. Thus process linkage, even when refined to cover absences and/or to require probability raising, is not sufficient for causation.

In disconnections and traces it seems as if the causal relation tracks the probability-raising relation rather than the process-linkage relation. The disconnecter is a probability raiser while the trace noncause is not (the sabotage makes the crash more likely while the stray photon does not make the window shattering more likely).

The four problem cases rendered above interlock to form a single problem space that no extant account of causation can navigate:

Problem Space: the preempting cause (1) and trace noncause (4) are both process linked to, but not probability raising of, the effect in question.

The disconnecting cause (3) and fizzled noncause (2) are both probability raising of, but not process linked to, the effect in question.

An adequate account of causation must explain the causally relevant difference between preemptors and traces, and between disconnectors and fizzlers (vandals and saboteurs are causes, while failed van-

²³ Salmon, whose theory of explanation was subjected to a related critique by Hitchcock (in "Discussion: Salmon on Explanatory Relevance," *Philosophy of Science*, LXII (1995): 304-20), has conceded this point for explanation: "As a result of Hitchcock's analysis, I would now say...that connecting causal processes, in the absence of statistical relevance relations, also lack explanatory import"—"Causality and Explanation: A Reply to Two Critiques," *Philosophy of Science*, LVIX (1997): 461-77, here p. 476. I would add that, given how entwined causation and explanation are (especially for Salmon), the same should hold for causation.

dals and bystanders are not). Neither the probability-raising nor the process-linkage relation, however interpreted and however refined, can reveal the nature of causation on their own.

III. PROBABILITY RAISERS OF PROCESSES

Causation, I here propose, is rooted in the comparative probability of the connecting line to the effect with the cause versus without. This approach synthesizes the probability-raising and process-linkage views and successfully navigates the problem space mapped above.

For starters, consider:

Analysis 1: C causes E if and only if C is a (P)robability (R)aiser (O)f a (P)rocess for E (for short: C is a PROP for E).

The idea is that, to assess if C causes E , first identify the actual process(es) linked to E , and second assess the probabilistic relevance of C , not to E , but to the comparatively extended event that comprises the E -process (or one of them in *overdeterminations* with multiple processes). The E -process, for a given candidate cause C , is to be traced back to the time of C , and may or may not include C . In worlds in which the causal order is the temporal order, the E -process runs the closed interval $[t_C, t_E]$, and in most actual world cases the E -process may be thought of as the energy lines in $[t_C, t_E]$ converging on E (an E -process is thus *not* the “causal intermediaries” between C and E).

Given the counterfactual chance understanding of probability raising and the nomic subsumption understanding of process linkage sketched above, Analysis 1 may be further interpreted as:

Analysis 1 Interpreted: C is a PROP for E if and only if (i) there is an extended event ‘ E -line’ containing actual distinct events $\langle C', D_1, D_2, \dots, D_n, E \rangle$ in pairwise nomic subsumption relations, (ii) there is an actual event C at t_C' which is distinct from D_1, D_2, \dots, D_n , and E (C may or may not be distinct from C'), (iii) $\text{ch}(E\text{-line})\text{-at-}t_C = p$, and (iv) $\neg C \square \rightarrow \text{ch}(\langle E\text{-line} \rangle)\text{-at-}t_{\neg C} < p$.

This interpretation of Analysis 1 is compatible with a purely “Humean” metaphysic of just occurrent properties and space-time, given a prior Humean account of laws, chances, and counterfactuals. Of course, other interpretations are available: even the causal primitivist may accept Analysis 1 as revealing how the notions of *probability* and *process* derive from primitive causation.

Analysis 1 synthesizes the probability-raising and process-linkage views. Analysis 1 may be thought of as a development of the precision strategy for the probability-raising view. Lewis considers precision with respect to time, precision with respect to manner, and precision

with respect to causal origins. He rejects precision with respect to time and/or manner as oversensitive to spurious influences, and rejects precision with respect to causal origins as trivializing the account of causation. But there is a fourth possibility (which is neither oversensitive nor trivializing): precision with respect to lawful origins. If we think of E as having its lawful origins essentially, then E exists if and only if E -line exists. It would then follow that C is a probability raiser of E -line if and only if C is a probability raiser of E -with-its-actual-lawful-origins.²⁴

Analysis 1 may also be thought of as an extension of the absence-covering strategy for the process-linkage view. Fair, who saw that absences can be causal, extended his view by considering counterfactuals about processes:

- (1) C causes E if and only if (a) C and E occur, and (b) C is physically connected to E .
- (2) C causes $\neg E$ if and only if (a) C occurs and E does not, and (b) C is physically connected to an E' incompatible with E .
- (3) $\neg C$ causes E if and only if (a) C does not occur and E does, and (b) had C occurred it would have been physically connected to an E' incompatible with E .
- (4) $\neg C$ causes $\neg E$ if and only if (a) neither C nor E occurs, and (b) had C occurred it would have been physically connected to E .

In the case where E is an absence, think of the E' incompatible with E as the *manifestation* of E 's absence: if E is the absence of beer in the fridge, its manifestation is the fridge actually being stuffed with milk, grapes, and air. If we think of the ⟨Property, Region⟩ pair of absent E s as ⟨Manifestation, Region⟩, then Analysis 1 can be seen as both a unified generalization over, and indeterministic extension of, Fair's four cases, all of which can now be seen to relate how the E -manifestation process depends on whether or not C occurs.

Thus Analysis 1 is a true synthesis of the probability-raising and process-linkage approaches, in that it not only explicitly incorporates both notions, but also extends the leading refinements of these approaches to convergence.

Analysis 1 also explains the success of counterfactual accounts of causation. In the deterministic case, if C and E both occur and E counterfactually depends on C , then it follows that whatever process

²⁴ Analysis 1 is still preferable to lawful-origin precision, since the latter makes dubious claims about event essences (though perhaps the essentiality of lawful origins of events is defensible on analogy with the essentiality of parental origins of persons), and obscures just how much of the work of the theory consists in spelling out an appropriate account of lawful origins.

actually produced *E* must depend on *C* (else *E* would still occur absent *C* via this independent process), so *C* is a PROP for *E*. In the other direction, if *C* is a PROP for *E* and there is no other *E*-process (no redundant causation) then *E* will counterfactually depend on *C*. Thus Analysis 1 explains why, at least in the deterministic case, the counterfactual account of causation proves such an excellent account, except for the seemingly intractable difficulties created by redundant causation (overdetermination and preemption).

Analysis 1, moreover, yields a unified and informative solution to the problem space rendered above. Consider a given candidate cause *C*. If the *E*-process includes *C*, then *C* is a PROP for *E* if and only if *C* is an essential part of the *E*-process: without *C*, if *E* still occurs it is via a different process entirely, rather than the same process slightly altered. If the *E*-process does not include *C*, then *C* is a PROP for *E* if and only if *C* is a shield for the process: without *C*, the chance of that same process running to completion would have been less. Analysis 1 is satisfied by essential parts of, as well as shields for, processes. With this the problem cases above all fall into line.

In preemptions, the preemptor comes out a cause because it is an essential part of the *E*-process: without the preemptor, even though *E* still occurs it is by a different process entirely, namely, by the backup process. In the case of Pam and Bob, the window-shattering process (assessed from the time of Pam's throw) is the sequence of events of her throwing the brick, her brick flying ever closer to the window, hitting it, and producing waves of force that shatter it. Pam's throw is a part of this process and an essential part, since without it if the window gets shattered at all it will be by a different process entirely: Bob's process. This solution extends to trumpings, given a suitably general conception of process to appreciate that the trumper (major) is on the process to the effect and the backup (sergeant) not.²⁵

Traces, however, come out noncauses because they are inessential parts of the *E*-process: without the trace, *E* still occurs by the same process slightly altered. Thus, without the traces of Tom's watching, the process by which Pam throws her brick through the window would be in essence the same, minus a few irrelevant stray photons.²⁶

²⁵ Applying the lawful sequence analysis of processes: there are trumping laws linking ranking orders to decisions. Since the major's order is the ranking order, only the major's order, not the sergeant's, instantiates the antecedent. The corporal's decision instantiates the consequent.

²⁶ We get along perfectly well without a defined counterpart relation for events, persons, tables, and the like, so in this respect processes are on par with the other furniture of the world. Our robust intuitions serve us sufficiently well.

There is a continuum of cases between traces and genuine causes (just imagine the dust mote from Tom swelling until it is as impactful as Pam's brick), and obviously we cannot determine at which point noncause turns into cause. Likewise, there is a continuum of cases between the same process slightly altered and a different process entirely. So our understanding of the causally relevant difference between preempting causes and trace noncauses is vague along exactly the same continuum as our understanding of the counterpart relation for processes: *analysans* swings with *analysandum*. Thus Analysis 1 not only explains the causally relevant difference between preemptions and traces (essential versus inessential process parts), but does so in the right way to mirror the logical structure involved.

In disconnections, the disconnector comes out a cause because it shields the *E*-process from what otherwise might have interrupted it: without the disconnector, the chance of the *E*-process running to completion would have been less. In the sabotage case, the crashing process consists in the main of the plane flying mountainward through the relevant interval and then crashing. Without the sabotage, the chance of this process would have been less, because the alert would then have been transmitted and the pilot would then have turned the plane away. Thus the sabotage shields the crashing process from the alert.

Fizzlers, in contrast, come out noncauses because they are neither essential parts of, nor shields for, the *E*-process. Thus Fred's misfiring is neither a part of nor a shield for the process by which Pam throws her brick through the window. This solution extends to overlappings, given a suitably general conception of process to appreciate that the cause (U238) is connected to the effect and the noncause (Ra226) not.²⁷

IV. REFINEMENTS

Analysis 1, which identifies causes with probability raisers of processes, while an improvement over its predecessors with respect to the space of problems discussed above, is subject to (at least) three objections. First, the account fails to provide for the *transitivity* of causation. There are cases (example to be given shortly) in which *C* is a PROP for *D* and *D* is a PROP for *E*, but *C* is not a PROP for *E*. Second, the account fails to provide for the *continuity* of causation. It

²⁷ Applying the lawful sequence analysis: since the decay laws are $U238 \rightarrow (Th234 \text{ \& } \alpha)$ and $Ra226 \rightarrow (Rn222 \text{ \& } \alpha)$, the absence of Rn222 shows that the consequent of the radium decay law is not instantiated. Thus the process in question is not radium decay. Rather, as the presence of Th234 shows, the process in question is uranium decay.

seems that, at least in the actual world (leaving the mysterious EPR correlations of quantum mechanics out of the discussion), all causation involves spatiotemporally continuous chains of causal intermediaries. But there are actual-world-ish cases (example to be given shortly) in which *C* is a PROP for *E* but there are gaps in the line of PROPs from *C* to *E*. Third, the account is subject to counterexample from preemptive disconnections.

All three objections can be brought out in the following case, which feeds a preemption case into a disconnection (*preemptive disconnection*). Pam and Bob are out to sabotage the radio tower and prevent an alert from reaching the pilot. Pam places her puny bomb (.1 chance of blowing up the tower), while Bob is too overcome with laughter to proceed (he would have almost certainly blown up the tower had Pam not distracted him). Pam's bomb then actually succeeds in destroying the tower (preemption), and so the alert is prevented, and so the plane crashes (disconnection):

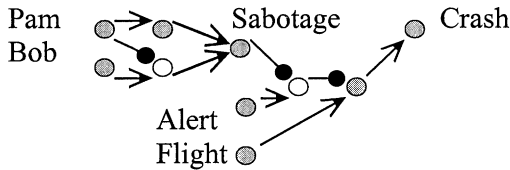


DIAGRAM 4

Pam's sabotaging is clearly a cause of the crash and Bob's is not, but Analysis 1 unfortunately gets this backward. Pam's sabotaging is a probability lowerer of the crash process (which consists, in the main, of the plane flying mountainward through the relevant interval): since Bob is a more reliable saboteur, the plane's chances would have been worse with Bob in action. And Bob's sabotaging is a probability raiser of the crash process, given that there was some chance he might have managed not to get distracted by Pam. In short, Pam is a preempting shield and Bob a fizzled shield for the crash.

It is worth noting that preemptive disconnections are everyone's problem (*tu quoque*). Probability-raising accounts get them backward generally, since Pam is a preemptor and Bob a fizzler. Process-linkage accounts get it right that Bob is a noncause, but only because they cannot count Pam as a cause at all since she is a disconnector.

Preemptive disconnections also illustrate the intransitivity and discontinuity of Analysis 1. Intransitivity: Pam's sabotaging is a PROP of the destruction of the tower, which is a PROP of the crash, but as per above her sabotaging is not a PROP of the crash. Discontinuity: Bob's sabotaging is a PROP of the crash, but there is a discontinuity where he fizzes.

I see two options. First, one might bite the bullet on all three objections. Transitivity has been questioned before,²⁸ continuity is equally questionable, and perhaps one could learn to live with a counterintuitive verdict in preemptive disconnections, especially as long as no alternative analysis of causation fares better.

A second option, which I prefer, is to refine the analysis. It turns out that all three objections can be handled, and the original solutions to preemptions, traces, disconnections, and fizzlings maintained, by adding a continuity requirement.

So I propose:

Analysis 2: C causes E if and only if C is a continuous PROP for E.

The continuity in question must be with respect to something, and the obvious candidate is space-time. Thus (at least in worlds for which the causal order is the temporal order), I further interpret Analysis 2 as:

Analysis 2 Interpreted: C is a continuous PROP for E if and only if there is a chain of direct PROPs between C and E, where C is a direct PROP for E if and only if (a) C is a PROP for E, and (b) for all times t_D between t_C and t_E , there is a D at t_D such that C is a PROP for D, and D is a PROP for E.

Analysis 2 answers the transitivity and continuity objections, while handling preemptive disconnections. Transitivity is gained, because if C causes D and D causes E then it follows that there is a chain of direct PROPs between C and D, and between D and E, and therefore a chain of direct PROPs between C and E. Continuity is gained explicitly. And in the preemptive disconnection case above, Pam's sabotaging will

²⁸ Hartry Field proposes the following counterexample to transitivity: your enemy places the bomb by your door (C), which causes your friend to defuse the bomb (D), which causes you to survive to eat breakfast next morning (E). But surely your enemy placing the bomb by your door (C) does not cause you to survive to eat breakfast (E)! As the reader may confirm in this example, C is a PROP for D (as an essential part of the D-process), D is a PROP for E (as a shield of the E-process), but C is not a PROP for E. For further proposed counterexamples to transitivity, see also Michael McDermott, "Redundant Causation," *British Journal for the Philosophy of Science*, XL (1995): 523-44; Hall (*op. cit.*) and "Causation and the Price of Transitivity," this JOURNAL, XCVII, 4 (April 2000): 198-222.

count as a direct PROP of the blowing up of the tower, and the blowing up of the tower will count as a direct PROP of the crash, and so Pam will come out a cause. Bob, on the other hand, cannot be connected to the crash by direct PROPs because there is a discontinuity involved at the point where he is overcome with laughter and fizzles out: there is no event D to be found at that time such that both Bob's sabotaging is a PROP for D and D is a PROP for the crash (Bob's laughter fails the latter).²⁹

As the reader may confirm, Analysis 2 preserves the solutions to preemptions, fizzlings, disconnections, and traces. The preemptor will count as itself a direct PROP (no chaining needed) of the effect, with the continuous path of the preempting process providing the relevant continuously present D events. The fizzler will not count as a direct PROP of the effect and no chaining of direct PROPs will rebuild a connection, since the fizzle point will always constitute a discontinuity. The disconnecter will count as a direct PROP, with the continuous D events being the sequence of events of the destruction of the tower, followed by the sequence of absences of the alert transmission to the pilot, followed by the sequence of the pilot maintaining course. And the trace will not count as a direct PROP and no chaining of direct PROPs will rebuild a connection, since though there is a continuous PROP sequence of the trace arriving at the effect, the irrelevance of any part of that sequence to the end always remains.

But there is a price to be paid: it looks as if a continuity requirement must stipulate away the seeming possibility of spatiotemporally discontinuous causations.³⁰ If Merlin casts a "prince to frog" spell at noon and the prince turns into a frog at midnight, and there is a law directly connecting magic spells at noon to enchantments at midnight, then it seems that Merlin's spell is a discontinuous cause of the enfrobbing. Analysis 1 has no problem with such cases: the process involved will be the two-membered sequence ⟨spell, enchantment⟩, and the spell will be an essential part of such a sequence. But Analysis 2 will find no event D at, for example, 6:00 pm such that Merlin's spell is a PROP for D , and D is a PROP for the enfrobbing.

²⁹ If we merely take the transitive closure of Analysis 1, this will fail to exclude Bob.

³⁰ If there is some independent way of defining the "causal dimension," then the PROPs relation can be required to be continuous with respect to that dimension rather than space-time. This would solve the problem, but I do not know how to define such a dimension.

I see three options: retreat to Analysis 1, bite the bullet and declare discontinuous causation impossible,³¹ or refine the analysis further to maintain the original solutions, handle preemptive disconnections, and allow discontinuous causation.

The causally relevant difference between Bob the fizzled shield and Merlin the successful spellcaster seems to be that, although both are PROPs for their respective *Es*, there is a causal gap in the line of PROPs from Bob's sabotaging to the collision, and no causal gap in the PROP relation from Merlin's spellcasting to the enchantment. If one can determine which PROP relations need intermediaries and which do not (obviously without relying on causal or temporal gaps) then one can require continuity with respect to needed intermediaries only, rather than with respect to space-time, and thereby achieve a successful further refinement.

But I do not know how to determine when intermediaries are needed. Some not implausible suggestions are available: perhaps one can study whether *C* remains a PROP for *E* on the counterfactual supposition of certain candidate needed-intermediaries not occurring, or perhaps one can study whether there are intermediaries *D* (where *C* is a PROP for *D* and *D* is a PROP for *E*) in certain unproblematic exemplars of such a *C* causing such an *E*. I do not know whether these suggestions will work generally. More work remains to be done.

The nature of the causal relation remains mysterious, but I believe that in important respects both Analysis 1 and Analysis 2 shed more light on this relation than any extant alternatives, and that there may be some Analysis 3 nearby that will yield complete success. I conclude that causes are best understood as probability raisers of processes, though exactly how best the story goes remains an open question.

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³¹ Mellor (*op. cit.*) regards spatiotemporal continuity as a central connotation of causation, and the other successes of Analysis 2 may be taken as an indirect argument for Mellor's claim.

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[Footnotes]

⁸ **Wesley Salmon's Process Theory of Causality and the Conserved Quantity Theory**

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²⁸ **Causation and the Price of Transitivity**

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