Proportionality in Causation, Part I: Theories[1]

Abstract: A much-discussed idea in the causation literature is that it is preferable to invoke causes which are proportional to — neither too general nor too specific for — the effect. This article presents various ways of understanding this idea. In what sense are such causal claims 'preferable'? And what is it for one event to be 'proportional' to another? In a companion article, 'Proportionality in Causation, Part II: Applications and Challenges', I discuss the principal applications of the various theories of proportionality, and the challenges they face.

1. Introduction

Consider the following pairs of causal claims:

1. a) The bolt's snapping caused the bridge to collapse.
   b) The bolt's snapping suddenly caused the bridge to collapse.

(Davidson 1967: 703)

2. a) Someone's coughing caused the conductor's annoyance.
   b) Fred's coughing caused the conductor's annoyance.

(Jackson & Pettit 1988: 394)

3. a) Socrates's drinking the hemlock caused his death.
   b) Socrates's guzzling the hemlock caused his death.

(Yablo 1992a: 275)

4. a) The burglar's believing that there was a diamond in the house caused him to ransack the house all night.
   b) The burglar's knowing that there was a diamond in the house caused him to ransack the house all night.

(Williamson 2000: 62)

5. a) A weight greater than 1000kg being placed on the platform caused it to collapse.
   b) A weight of 1600kg being placed on the platform caused it to collapse.

(Woodward 2008: 227)

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In each pair, the putative cause is more general in the first claim, and more specific in the second.[2] This seems to impact the evaluation of these claims. For example, suppose the suddenness of the bolt's snapping is needed for the bridge's collapse (perhaps the bridge has some redundancy mechanism which would have safely redistributed the weight had the bolt snapped gradually). Then there is a sense in which (1b) is preferable to (1a): the bolt's merely snapping is too general. If the suddenness is not needed, however, then there is a sense in which (1a) is preferable: the bolt's snapping suddenly is too specific. This phenomenon appears ubiquitous: for any causal claim of the form 'c caused e', we can consider whether c is too general (missing needed detail) or too specific (containing unneeded detail) for e. If it is, then a nearby causal claim which invokes some more or less detailed cause seems preferable.

Causes which are neither too general nor too specific are said to be 'proportional' to their effects. This article overviews the main attempts to capture this phenomenon of proportionality. (In a companion article, 'Proportionality in Causation, Part II: Applications and Challenges', I consider the principal applications of the resulting theories, and the challenges they face.) Formulating a precise principle to capture the phenomenon illustrated by (1) – (5) requires clarifying the sense in which proportionality is 'preferable' (§2), as well as characterizing proportionality itself (§§3-4). It is worth bearing in mind that the examples above are quite heterogenous, and so it is possible that an adequate treatment of them all will require some combination of the approaches outlined below.[3]

2. 'Preferable'

In some sense, causal claims which invoke causes that are neither too specific nor too general for their effects seem 'preferable', or 'better'. In what sense? This section distinguishes three broad kinds of answer to this question.

[2] On a coarse-grained view of events, some of these causal claims differ not on the event they invoke as cause but merely on how they describe this event. This leads to a conception of proportionality as pertaining to event-descriptions rather than events, suggesting an epistemic or pragmatical construal (discussed below). I will speak in terms of events throughout, but the characterizations of proportionality discussed in §§3-4 can be adapted to the setting of event-descriptions.

[3] With the possible exception of (4), the examples above all seem to involve causes which plausibly pertain to the same spacetime region. Causes can also differ on the size of the region they encompass, but — following the literature — my focus will mainly be on causes which differ on how much of what is going on within a given region they involve (cf. Yablo 1992b: §2).

2.1 Metaphysical proportionality

On a 'metaphysical' construal, proportionality is tied to the truth of causal claims.[4] Most straightforwardly, proportionality is necessary for truth: if c causes e, then c is proportional to e. For example, if the bolt's sudden snapping is not proportional to the bridge's collapse, then (1b) is false. This view (sometimes called 'strong proportionality') is commonly discussed but rarely endorsed; List & Menzies 2009 and Strevens 2004, 2008 are prominent exceptions.[5] The idea that causation is proportional combines naturally with the recognition of other causal relations: events or facts which are too specific may nonetheless be said to be 'causally sufficient', and those which are too general may be 'causally relevant' (Yablo 1992a: 273; cf. McDonald 2022: 110). For it to be a substantive question whether *causation* requires proportionality, then, we require some suitably independent grip on the relevant notion. (For example, perhaps proportional causation bears distinctive connections to explanation and/or moral responsibility.)

List & Menzies 2009 suggest that proportionality as sufficient for causation. Another idea is that proportionality makes up the difference between some minimal causal notion — such as Lewisian causal influence (Strevens 2004, 2008), or counterfactual dependence (Yablo 2003) — and causation itself. Less straightforwardly, it might be that true causal claims maximize degree of proportionality (perhaps given certain other constraints), or best balance proportionality with some other virtue(s) against which it is traded off. This is suggested by some of Yablo's (1992a, 1992b, 1997, 2003) remarks. For example, he writes that proportionality should not be regarded as a necessary condition for causation, but that 'faced with a choice between two candidate causes, normally the more proportional candidate is to be preferred' (1992a: 277), and announces that 'proportionality is not to be pursued at all costs but traded off against naturalness' (2003: 326).

Given the orthodox assumption that causation is a binary relation, a metaphysical approach to proportionality requires a reasonably fine-grained view of its relata. For example, if (1a) and (1b) have different truth-values, the expressions 'the bolt's snapping' and 'the bolt's snapping suddenly' must not co-refer.[6] This approach is thus naturally combined with the view that the causal relata are property-object-time triples (Kim 1976), facts (Bennett 1988), or property-instances (Paul

[4] I am ignoring here complications arising from a potential gap between the truth of causal claims as made within particular conversational contexts and the underlying metaphysics of causation itself. Contrastivists, for example, might view causation as a four-place relation which is unconstrained by proportionality, and yet view proportionality as constraining the truth of causal claims (at least in typical contexts).

[5] The view is sometimes attributed erroneously to Yablo. For proponents, see also Papineau 2013, Zhong 2014, 2022, Franklin-Hall 2015, Touborg 2022, and McDonald 2022: ch.5.

[6] As Schaffer (2005: 347) notes, contrastivism may do the work of a fine-grained view. In this case, contrastivists may hold that (1a) and (1b) invoke the same cause but trigger different causal contrasts.

2000). Yablo (1992b) proposes a kind of 'modal plenitude' view of events, on which there is one bolt-snapping which is essentially sudden and another co-located bolt-snapping which is only accidentally sudden. (I will speak of 'events' throughout, but this is intended to be neutral on the background metaphysics.)

2.2 Epistemic proportionality

An 'epistemic' construal ties proportionality to the explanatoriness rather than the truth of causal claims. This involves separating causation and causal explanation (to some extent): for those who hold that causal claims assert an explanatory relation, their explanatoriness and their truth stand and fall together (Strevens 2008: 51).[7]

According to the most straightforward version of the epistemic construal, explanation requires proportionality: if c causally explains e, then c is proportional to e. For example, on this view, if the bolt's snapping suddenly is not proportional to the bridge's collapse, then it does not causally explain the collapse, so (1b) fails to be explanatory (even though it may nonetheless be true). Davidson suggests a view along these lines, on which different descriptions of the same event differ in explanatoriness. For example, he (1967: 703) holds that there is only one bolt-snapping, but if its suddenness is relevant to the collapse, then only the description of it as a sudden bolt-snapping explains the collapse.

A slightly different view is suggested by Jackson & Pettit (1988: 394). They hold that general facts/states may causally explain certain effects without causing them (by 'programming' them). For example, the conductor's annoyance may in fact have been caused by Fred's coughing, whilst what causally explains the annoyance is the general fact that someone coughed. This suggests a view on which proportionality constrains causal explanation — or at least, a certain kind of causal explanation, which they call 'program explanation' —without constraining causation itself.

More recently, Weslake (2010, 2013, 2017) and Woodward (2010, 2018, 2021) have defended the view that true causal claims may have more explanatory 'value' or 'depth' depending (at least in part) on how proportional they are.[8] These authors employ an interventionist framework in which a weak form of counterfactual dependence suffices for causation. For example, even if the suddenness is irrelevant, the bolt's snapping suddenly is nonetheless a cause of the bridge's

[7] 'To some extent' because one might hold, like Woodward (2021: 364), that all true causal claims are explanatory to some degree, so that 'there is no sharp contrast between causal claims and causal explanations', whilst tying proportionality to degree of explanatoriness.

[8] This view is also endorsed by McDonnell (2017: §6).

collapse, since there is an 'intervention' on the bolt snapping suddenly which would prevent the collapse (namely, one which stops the bolt snapping altogether). However, the bolt's merely snapping provides a better explanation of the collapse, since it is more proportional.

2.3 Pragmatic proportionality

A 'pragmatic' construal ties proportionality to assertability, rather than truth or explanatoriness. This approach seeks to explain why we intuitively prefer proportional causal claims without invoking any corresponding constraint on causation or explanation.[9]

Bontly (2005: §5) suggests that the preference for proportionality may derive from Grice's 'maxim of Quantity': roughly, assert enough to satisfy the purposes of the conversation but no more. For example, by asserting (1b), a speaker implicates (in a standard context) that the suddenness of the snapping was relevant to the bridge's collapse, since otherwise their assertion would be more informative than necessary. Hence, if the suddenness was irrelevant, (1b) has a false implicature (though it may still be true). However, as Maslen (2017: 63) points out, it is unclear that more specific causal claims like (1b) are strictly more informative than less specific causal claims like (1a). For example, given a view on which causes suffice for their effects in some sense, (1a) conveys the information that the bolt's snapping (gradually or suddenly) suffices for the bridge's collapse, whereas (1b) does not.

Maslen (2017) proposes an alternative pragmatic explanation. Like Woodward (2008: 225–7), she invokes a contrastivist theory of causation on which 'c caused e' is true so long as there are some (relevant) contrasts c* and e* for which c rather than c* caused e rather than e*. A true causal claim may nonetheless be defective (in a given context) if it fails to make the relevant contrast clear. For example, (1b) may be defective because it misleadingly suggests the false contrastive claim 'The bolt's snapping suddenly rather than gradually caused the bridge to collapse rather than not collapse'. Maslen argues that this accommodates our tendency to regard overly specific causal claims as acceptable (at least in some contexts) — since there is some relevant contrast making them true — whilst regarding more general claims as improving them by clarifying the relevant contrast. (Maslen rejects the converse preference, for claims which aren't too general. For those who don't, it requires some further explanation. For example, suppose the suddenness is needed, so that (1a) is too general. If (1a) is nonetheless true, then presumably so is its naturally suggested

[9] Weslake 2013 (cf. McLaughlin 2007:165) proposes that the preference for proportional causal claims derives from a norm favoring assertions with greater explanatory value; this is an epistemic rather than (purely) pragmatic approach.

contrastive claim 'the bolt snapping rather than not snapping caused the bridge to collapse rather than not collapse'.)

3. Comparative Approaches

So far, I have characterized proportional causes as those which are neither specific nor too general for their effects. In this section and the next, I discuss two different approaches to making this more precise.

'Comparative' approaches characterize the proportionality of a cause via a comparison to more specific/general alternatives. Following Yablo (1992a), I refer to more specific/general events as each other's 'determinates'/'determinables': for example, *the bolt's snapping suddenly* is a determinate of *the bolt's snapping*.

3.1 Screening off

Yablo's (1997: §15) classic definition revolves around the notion of 'screening off'. Intuitively, one event c screens off another event c* from some effect e when, holding c fixed, the presence or absence of c* makes no difference to the occurrence of e. For example, suppose Suzy throws a rock at the window whilst screaming. The rock-throwing screens off the screaming from the window-shattering: holding fixed the rock-throwing, the screaming makes no difference to the window-shattering. This can be captured in terms of counterfactuals as follows:

> c *screens off* c* from e iff (c & ~c*) > e
> i.e. had c occurred without c*, then e would still have occurred.[10]

For example, had Suzy thrown the rock but not screamed, the window would still have shattered. Yablo uses this notion to formulate the following definitions:

> c is *enough for* e iff c screens off all its determinates from e.

> c is *required for* e iff none of c's determinables screens it off from e.

[10] It may instead be defined probabilistically (à la Reichenbach 1956):

> c *screens off* c* from e iff Pr (e | c & c*) = Pr(e | c)

i.e. holding c fixed, c* makes no difference to the chance of e.

c is *proportional for* e iff c is both enough and required for e.[11]

For example, suppose that the bridge might not have collapsed had the bolt snapped gradually. Then the bolt's snapping is not enough for the bridge's collapse, since it fails to screen off the bolt's snapping suddenly: it is not the case that if the bolt had snapped, but not snapped suddenly, then the bridge would have collapsed. Conversely, suppose that the bridge would still have collapsed had the bolt snapped gradually. Then the sudden snapping is not required for the collapse, since it is screened off by the snapping: had the bolt snapped, but not snapped suddenly, then the bridge would still have collapsed.

3.2 Causal sufficiency

An alternative definition revolves around 'causal sufficiency' (where this may be reduced to causal laws and/or other modal/nomic notions):

> c is *proportional* to e iff c is causally sufficient for e and no determinable of c is causally sufficient for e.

In other words, proportional causes are 'maximally general sufficers' (Rubenstein forthcoming). For example, if the bolt's snapping is causally sufficient for the bridge's collapsing, then the bolt's snapping suddenly is too specific to be proportional (and the bolt's snapping is proportional, assuming that none of its determinables are themselves causally sufficient). Conversely, if the bolt's snapping is not causally sufficient for the bridge's collapsing, then it is too general. Strevens (2004, 2008) develops and defends a version of this approach (albeit not employing the 'proportionality' terminology).[12] Franklin-Hall (2015, forthcoming) develops an approach in the same spirit, though it involves a non-comparative notion of abstraction. On her 'causal economy' account, causes/causal explanations best balance 'abstraction' (roughly, in how many worlds the cause occurs), and 'stability' (roughly, how much more robust the cause makes the effect).

3.3 Determination

In light of these definitions of proportionality, how is the key notion of determination — the relation between determinate and determinable events — to be understood? Considering how

[11] This differs slightly from the formulation in Yablo (1992a, 1992b). Officially, Yablo also requires two further conditions similar to those in §4.1, but these seem redundant (Jäger 2021).

[12] Strevens speaks in terms of difference-making causation/causal explanation rather than proportionality, and in terms of the abstraction of a causal model rather than determination. See also Weslake 2010. Mackie 1974, Putnam 1975, Garfinkel 1981 and Jackson & Pettit 1988 are important precursors.

central this issue is for comparative approaches, it has been strangely under-discussed in the literature. One possibility, suggested by Yablo (1992a: 260), is to regard the notion as a natural extension of the traditional determinate-determinable relation between properties to the case of events.[13] The extent to which this fits all the relevant examples is unclear, however. For example, 'conjunctive' events like the man's falling into the water and being unable to swim, do not seem to determine their conjuncts, like the man's falling into the water. And Bernstein (2014) argues that determination doesn't fit omissions, like no one's watering the plant and the gardener's not watering the plant.[14]

On a straightforward modal characterization, c* determines c iff the occurrence of c* metaphysically necessitates the occurrence of c. Without some further restriction, this makes proportionality extremely demanding: for any cause of e, c1, and downstream causal intermediary c2, disjoining c1 and c2 yields a determinable which screens off c1 from e and suffices for e. For example, suppose that the rock's being thrown determines the rock's either being thrown or hitting the window. Then the rock's being thrown turns out not to be 'required' for the window-shattering, in the sense of §3.1: if the rock had hit the window without being thrown, then the window would still have shattered. Moreover, since the rock's either being thrown or hitting the window suffices for the window-shattering, the rock's being thrown is not a maximally general sufficer in the sense of §3.2.

This problem not only affects the straightforward modal characterization, but also characterizations in terms of grounding, truthmaking, and conjunctive/disjunctive parthood. It may be avoided by following Lewis (1986a: §VIII) in banning disjunctive events (pending some way of accounting for 'disjunctiveness'). Some such constraint will arguably be needed however proportionality is characterized (see §3 of the companion article). However, the modal characterization also entails that conjunctions determine their conjuncts, which raises similar issues. For example, consider the event of the rock's being thrown and hitting the window. If this event determines the rock's being thrown, then the rock's being thrown turns out not to be 'enough' for the window-shattering, in the sense of §3.1: it is not the case that, had the rock been thrown without being thrown and hitting the window, the window would still have shattered. Conversely, the rock's being thrown and hitting the window fails to be a maximally general sufficer in the sense of §3.2, since the rock's being thrown is a determinable of it which suffices.

[13] See Funkhouser (2006) for an account of the traditional relation. Yablo himself goes on to develop an elaborate account in terms of essence.

[14] See §2.3 of the companion article for discussion of proportionality's application to absence causation.

If events are constitutively tied to time-intervals/spacetime regions, then this issue might be avoided by restricting determination to events which pertain to the same interval/region.[15] A more demanding restriction requires that events differ from their determinates only on the properties they involve. For example, given Kim's (1967) tripartite conception of events, we might offer the following account:

> c* determines c iff for some object x, time t, and properties P and P*: c* = <x, t, P*>, c = <x, t, P>, and P* is a determinate of P.

This proposal has the potential drawback of failing to cover abstraction with respect to objects and/or times. In the case of (2), for example, it entails that Fred's coughing does not determine someone's coughing (since they both involve the same property of *coughing*).[16]

4. Non-comparative Approaches

Non-comparative approaches evaluate the proportionality of a cause to its effect without any direct comparison to more specific/general alternatives (and so don't need to appeal to any notion of determination).

4.1 Counterfactual covariation

List & Menzies (2009) (cf. Menzies 2008: §4) define proportionality in terms of counterfactuals as follows:

> c is *sufficient for* e iff c > e.[17]
>
> c is *necessary for* e iff ~c > ~e.
>
> c is *proportional for* e iff c is both necessary and sufficient for e.

[15] It might also be avoided by taking causal processes (rather than individual events) to stand in determination relations (in the spirit of Strevens 2008).

[16] In light of the problem of spurious generality, discussed in the companion article, this may turn out to be an advantage.

[17] In a slight abuse of notation, 'c' and 'e' are being used here to stand both for events and the propositions that they occur.

As List & Menzies note, sufficiency is trivialized if c > e is entailed by c & e (this assumption is known as 'Strong Centering'). Hence, c > e is to be understood as requiring that e be true across all 'relevant' situations in which c is true, where (in the case in which c actually occurs) this 'sphere' includes actuality but extends beyond it ('Weak Centering').[18] This approach is also defended by Zhong (2014, 2022), who argues that it is preferable to the idea that causes are proportional in the screening off sense.

Suppose, for example, that the bridge would not have collapsed if the bolt had snapped gradually rather than suddenly. Then — assuming that this is a relevant situation — the bolt's snapping fails to be sufficient for the collapse, and so is too general to be proportional. Conversely, suppose that the bridge would have collapsed if the bolt had snapped gradually. Then — again, assuming that this situation is relevant — the bolt's snapping suddenly fails to be necessary for the collapse, and so is too specific to be proportional. (Note that the notion of a 'relevant'/'relevantly similar' situation is playing the key role here.)[19]

4.2 Structural equations

'Structural equation models' provide a useful formalism for representing causation (Pearl 2000, Woodward 2003, Hitchcock 2009). There are many ways of interpreting the variables in these models and the structural equations which relate them. One natural understanding of variables is that their values correspond to propositions (or 'possible events/facts') which, intuitively, vary along some dimension of the situation being modeled. For example, we can introduce a binary variable WEIGHT, whose values 1 and 0 represent *the weight on the platform was greater than 1000 kg* and *the weight on the platform was not greater than 1000 kg* respectively, and another binary variable, COLLAPSE, whose values 1 and 0 represent *the platform collapsed* and *the platform didn't collapse* respectively.[20] Structural equations describe how the values of some

[18] An alternative approach requires that c > e be robustly or insensitively true (Lewis 1986b: postscript C, Woodward 2006) or uses the nested counterfactual ~c > (c > e) (Yablo 1992a: 274).

[19] An under-discussed non-comparative approach uses probabilities (Williamson 2000: §§3.5–6; cf. Woodward 2021: 377):

> c is too specific for e insofar as Pr (e | ~c) is high.
>
> c is too general for e insofar as Pr (e | c) is low.

Combining these desiderata yields the 'correlation coefficient': a straightforward degreed notion of proportionality. (Relevance may also play an important role here in characterizing the range of situations with respect to which the probabilities are evaluated.)

[20] Although it is more standard to focus on 'token causation', Woodward has consistently emphasized the use of variables to represent 'type-level' causal relations between properties in the context of discussing proportionality (e.g. 2008: 223; 2021: 258). It is not obvious to me how to understand the claim that, for example, the property

variable(s) 'causally determine' the values of another, where this might be understood in terms of causal sufficiency, ordinary counterfactuals or interventionist counterfactuals.[21] For example, suppose that the platform can only support weights up to 1000kg. This is described by the equation COLLAPSE = WEIGHT.

In a series of papers, Woodward (2008, 2010, 2018, 2021) has suggested that a degreed notion of proportionality for variables can be defined in terms of certain features of the structural equation connecting them. First, exhaustivity quantifies the degree to which the equation covers some (relevant) range of hypothetical situations.[22] For example, consider the variable:

WEIGHT*
1: *the weight on the platform was 1600 kg*;
0: *the weight on the platform was 800 kg*.

The structural equation COLLAPSE = WEIGHT* is not very exhaustive since it fails to cover situations in which the weight on the platform is anything other than 800kg and 1600kg.

Second, accuracy quantifies the degree to which the equation holds true across the (relevant) range of hypothetical situations which it does cover. For example, consider:

WEIGHT**
1: *the weight on the platform was 1600 kg*;
0: *the weight on the platform was not 1600 kg*.

The equation COLLAPSE = WEIGHT** is exhaustive but not very accurate since many hypothetical situations in which the weight is not 1600kg (those in which it is between 1000kg and 1600kg) are situations in which the platform still collapses.[23]

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of snapping causes the property of collapsing, in abstraction from the particular situation vis-à-vis the bolt and the bridge. One idea is that we are interested in which property is involved in the proportional cause (as opposed to which object and/or time), but this treats causation as a relation between 'token' events.

[21] On the truth-conditions for structural equations, see Hall 2006: §4, Gallow 2016 and McDonald 2022. On interventionist counterfactuals, see Briggs 2012.

[22] Where an equation 'covers' a situation when the parent variables take well-defined values at it.

[23] Depending on how structural equations are interpreted, this equation may nonetheless be 'true'. For example, it might be taken to mean that there is *some* intervention setting WEIGHT** to 0 which would prevent the platform's collapse (Woodward 2008:227, cf. 2021: 366; Weslake 2017: §4).

Finally, parsimony quantifies the degree to which an equation is injective or one-one i.e. how many changes in the value of the 'cause' variable are associated with changes in that of the 'effect' variable. For example, consider:

> WEIGHT***:
> x: *the weight on the platform was x kg*
> (where x ranges over the positive real numbers.)

The equation which maps COLLAPSE to 1 iff WEIGHT***> 1000 conveys full and (we are supposing) accurate information about the range of conditions under which the platform would collapse. However, it is not parsimonious since many values of WEIGHT*** map onto the same value of COLLAPSE, making the differences between them redundant.[24]

By contrast with WEIGHT*, WEIGHT**, and WEIGHT***, WEIGHT is proportional to COLLAPSE because the equation COLLAPSE = WEIGHT is accurate, exhaustive and parsimonious. More generally, variable X is proportional to variable Y to the extent that there is some equation Y = f(X) exhibiting these three virtues.[25]

(In response to criticisms from Shapiro & Sober (2012) and Franklin-Hall (2016) — discussed in §3.1 of the companion article — Woodward (2018, 2021) drops the parsimony requirement. This appears to undermine any preference for generality, since *any* sufficient cause — no matter how specific — can be represented by a maximally accurate and exhaustive model. For example, *the weight on the platform was 1600 kg* can be represented by a model connecting COLLAPSE to WEIGHT***.)

Singular causal claims most directly concern events rather than variables. Hence, in order to make contact with motivating examples like (1) – (5), any notion of proportionality for variables must somehow be translated into one which applies to events. There are different ways of doing this, but one approach is to pair causal claims with canonical or contextually salient models, where a natural default model contains the binary variables {c, ~c} and {e, ~e} (Woodward 2008:235-6, Menzies 2008:208, Raatikainen 2010:354). This threatens to make both parsimony and exhaustivity redundant, since the default model is maximally parsimonious and exhaustive. It is

[24] An alternative approach, in the spirit of Strevens 2004, 2008, would be to start with some maximally accurate and exhaustive model, such as that involving WEIGHT***, and apply an abstraction procedure.

[25] McDonald (2022: §5.4) proposes a non-degreed notion of proportionality for variables in structural equation models, which focuses on parsimony.

naturally thought of as yielding a degreed version of the counterfactual covariation approach in §4.1, with the accuracy of the equation quantifying the degree to which the cause is both sufficient and necessary for the effect.[26]

4.3 Relevance

Non-comparative approaches rely on the key notion of a 'relevant' (and/or 'relevantly similar') situation. In the case of counterfactual covariation, relevance is needed to account for the counterfactuals in question. In the case of structural equations, an equation is accurate to the extent that it holds across relevant situations, and exhaustive to the extent that all relevant situations are covered. For example, the platform would have collapsed had a 1kg bomb been placed on it. But this situation is not relevant for the purposes of evaluating either the truth of the counterfactual (*~the weight on the platform was greater than 1000 kg*) > (*~the platform collapsed*), or the accuracy of the equation COLLAPSE = WEIGHT.

Relevance is challenging to spell out.[27] It appears to differ from the notion tied to ordinary counterfactuals (Yablo 1992a:276, Weslake 2017:222, Jäger 2021:575). Suppose, for example, that had the bolt not snapped suddenly, it wouldn't have snapped at all. Nonetheless, if the bolt's merely snapping is sufficient for the bridge's collapsing, it seems that the bolt's snapping suddenly is too specific. Hence, the bolt's snapping gradually should be counted as relevant for the purposes of assessing counterfactual covariation, and accuracy/exhaustivity.

References

Bennett, J. (1988). *Events and their Names*. Indianapolis, IN: Hackett Publishers.

Bernstein, S. (2014). Two Problems for Proportionality about Omissions. *Dialectica* 68 (3):429-441.

Bontly, T. D. (2005). Proportionality, causation, and exclusion. *Philosophia* 32 (1-4):331-348.

Briggs, R. (2012). Interventionist counterfactuals. *Philosophical Studies* 160 (1):139-166.

[26] Alternative approaches make proportionality between events model-relative, or make it some function of all the corresponding models (e.g. the maximal degree of model-relative proportionality the two events have within the range of corresponding models).

[27] Menzies (2004) offers a model-relative proposal. Note that relevance may be spelled out differently in the case of counterfactual covariation and the case of structural equations.

Davidson, D. (1967). Causal relations. *Journal of Philosophy* 64 (21):691-703.

Franklin-Hall, L. R. (2015). Explaining Causal Selection with Explanatory Causal Economy: Biology and Beyond. In P.-A. Braillard & C. Malaterre (eds.), *Explanation in Biology: An Enquiry into the Diversity of Explanatory Patterns in the Life Sciences*. Springer. pp. 413-438.

—— (2016). High-Level Explanation and the Interventionist's 'Variables Problem'. *British Journal for the Philosophy of Science* 67 (2):553-577.

—— (forthcoming). The Causal Economy Approach to Scientific Explanation. *Minnesota Studies in the Philosophy of Science*.

Funkhouser, E. (2006). The Determinate-Determinable Relation. *Noûs* 40(3): 548-569.

Gallow, J. D. (2016). A theory of structural determination. *Philosophical Studies* 173 (1):159-186.

Garfinkel, A. (1981). *Forms of Explanation: Rethinking the Questions in Social Theory.* New Haven and London: Yale University Press.

Hall, N. (2006). Structural equations and causation (extended version). Manuscript at: *https://dash.harvard.edu/bitstream/handle/1/3710361/Hall_StructuralEquationsCausation.pdf*

Hitchcock, C. (2009). Causal Modelling. In H. Beebee, C. Hitchcock, & P. Menzies (Eds.), *The Oxford Handbook of Causation* (Vol. 1, pp. 299–314). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199279739.003.0015

Jackson, Frank & Pettit, Philip (1988). Functionalism and broad content. *Mind* 97 (July):381-400.

Jäger, J. (2021). List and Menzies on High-Level Causation. *Pacific Philosophical Quarterly* 102 (4):570-591.

Kim, J. (1976). Events as Property Exemplifications. In M. Brand and D. Walton (eds.), *Action Theory*, Dordrecht: Reidel, pp. 159–177.

Lewis, D. (1986a). Events. In *Philosophical Papers, vol. 2*. Oxford: Oxford University Press.

Lewis, D. K (1986). Causation (with Postscripts). In *Philosophical Papers, vol. 2*. Oxford: Oxford University Press.

List, C. & Menzies, P. (2009). Nonreductive Physicalism and the Limits of the Exclusion Principle. Journal of Philosophy 106 (9):475-502.

Mackie, J. L. (1974). *The Cement of the Universe*. Oxford: Oxford University Press.

Maslen, C. (2017). Pragmatic explanations of the proportionality constraint on causation. In Beebee, Hitchcock & Price (eds.), *Making a Difference: Essays on the Philosophy of Causation.* Oxford: Oxford University Press. pp.58–72.

McDonald, J. (2022). *Actual Causation: Apt Causal Models and Causal Relativism*. The Graduate Center, CUNY. http://academicworks.cuny.edu/gc_etds/4828

McDonnell, N. (2017). Causal exclusion and the limits of proportionality. *Philosophical Studies* 174 (6):1459-1474.

McLaughlin, B. P. (2007). Mental causation and Shoemaker-realization. *Erkenntnis* 67 (2):149 - 172.

Menzies, P. (2004). Difference-making in context. In J. Collins, N. Hall & L. Paul (eds.), *Causation and Counterfactuals*. MIT Press.

—— (2008). The exclusion problem, the determination relation, and contrastive causation. In J. Hohwy & J. Kallestrup (eds.), *Being Reduced: New Essays on Reduction, Explanation, and Causation*. Oxford University Press.

Papineau, D. (2013). Causation is Macroscopic but Not Irreducible. In Gibb, S. C., Ingthorsson, R. (Eds.), Mental Causation and Ontology. Oxford University Press, p. 126.

Paul, L. A. (2000). Aspect Causation. *Journal of Philosophy* 97 (4):235-256.

Pearl, J. (2000). *Causality: Models, reasoning, and inference*. New York: Cambridge University Press.

Putnam, H. (1975). Philosophy and our mental life. In *Mind, Language, and Reality*. Cambridge University Press.

Raatikainen, P. (2010). Causation, exclusion, and the special sciences. *Erkenntnis* 73 (3):349-363.

Reichenbach, H. (1956). *The direction of time*. Mineola, N.Y.: Dover Publications.

Rubenstein, E. (forthcoming). Cohesive Proportionality. *Philosophical Studies*.

Schaffer, J. (2005). Contrastive causation. *Philosophical Review* 114 (3):327-358.

Shapiro, L. A. & Sober, E. (2012). Against proportionality. *Analysis* 72 (1):89-93.

Shoemaker, S. (2001). Realization and mental causation. In Carl Gillett & Barry M. Loewer (eds.), *The Proceedings of the Twentieth World Congress of Philosophy*. Cambridge University Press. pp. 23-33.

Strevens, M. (2004) The causal and unification approaches to explanation unified—causally. *Noûs* 38(1): 154–176.

—— (2008). *Depth: An Account of Scientific Explanation*. Cambridge, Mass.: Harvard University Press.

Touborg, C. T. (2022). Relativizing proportionality to a domain of events. *Synthese* 200 (2):1-20.

Weslake, B. (2010). Explanatory Depth. *Philosophy of Science* 77 (2):273-294.

—— (2013). Proportionality, contrast and explanation. *Australasian Journal of Philosophy* 91 (4):785-797.

—— (2017). Difference-Making, Closure and Exclusion. In H. Beebee, C. Hitchcock & H. Price (eds.), *Making a Difference*. Oxford: Oxford University Press. pp. 215-231.

Williamson, T. (2000). *Knowledge and its limits*. New York: Oxford University Press.

Woodward, J. (2003). *Making Things Happen: A Theory of Causal Explanation*. Oxford University Press.

—— (2006). Sensitive and insensitive causation. *Philosophical Review* 115(1):1-50.

—— (2008). Mental causation and neural mechanisms. In Jakob Hohwy & Jesper Kallestrup (eds.), *Being Reduced: New Essays on Reduction, Explanation, and Causation*. Oxford University Press. pp. 218-262.

—— (2010). Causation in biology: Stability, specificity, and the choice of levels of explanation. *Biology and Philosophy* 25 (3):287-318.

—— (2018). Explanatory autonomy: the role of proportionality, stability, and conditional irrelevance. *Synthese* 198 (1):1-29.

—— (2021). *Causation with a Human Face: Normative Theory and Descriptive Psychology*. Oxford University Press.

Yablo, S. (1992a). Mental Causation. *Philosophical Review* 101: 245–80.

—— (1992b). Cause and essence. *Synthese* 93(3):403–449.

—— (1997). Wide causation. *Philosophical Perspectives* 11:251-281.

—— (2003). Causal relevance. *Philosophical Issues* 13(1): 316–28.

Zhong, L. (2014). Sophisticated Exclusion and Sophisticated Causation. *Journal of Philosophy 111 (7):341-360.*

—— (2022). Why Causation is Biconditional but not Proportional. *American Philosophical Quarterly* 59 (3):263-271.