<u>Proportionality in Causation, Part II: Applications and Challenges</u>[1]

Abstract: In 'Proportionality in Causation, Part I: Theories', I presented various ways of understanding the idea that causes which are 'proportional' to their effects are in some sense preferable. In this companion article, I discuss the principal applications of the resulting theories of proportionality, and the challenges they face.

1. Introduction

Proportionality is the idea that causes which are neither too specific nor too general for their effects are in some sense to be preferred. In 'Proportionality in Causation, Part I: Theories', I outlined the main answers to two questions:

    i)   In what sense are proportional causes preferable?

    ii)   What is it for a cause to be proportional to its effect?

With regards to (i): a metaphysical construal ties proportionality to the truth of causal claims, either as a necessary condition or as some form of desideratum (Yablo 1992a, 1992b, 1997, 2003; Strevens 2004, 2008; List & Menzies 2009). An epistemic construal ties proportionality to the explanatoriness, rather than the truth, of causal claims (Weslake 2010, 2013, 2017; Woodward 2010, 2018, 2021). Finally, a pragmatic construal ties proportionality to the pragmatic assertability of causal claims within a conversational context, rather than their truth or explanatoriness (Bontly 2005, Maslen 2017).

With regards to ii), I distinguished comparative and non-comparative ways of characterizing proportionality. Comparative characterizations employ the relation of determination which holds between events and their more general determinables. On the 'screening off' approach (e.g. Yablo 1997), proportional causes are those which screen off all their determinates, and are not screened off by any of their determinables.[2] On a 'causal sufficiency' approach (e.g. Strevens 2008),

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[2] Where 'screening off' is defined 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.

proportional causes are maximally general sufficers for their effects i.e. sufficers none of whose determinables are also sufficers.

Non-comparative characterizations revolve around the notion of a 'relevant' (or 'relevantly similar') situation. On a 'counterfactual covariation' approach (e.g. List & Menzies 2009), a cause is proportional if and only if it covaries with the effect across the relevant situations i.e. in situations where the cause occurs, so does the effect, and in situations where the cause is absent, so is the effect. A 'structural equations' approach (e.g. Woodward 2008), uses structural equation models to characterize proportionality between variables.[3] In particular, one variable is proportional to another (relative to a model) insofar as the equation connecting them: i) is 'exhaustive' i.e. covers all the relevant situations; ii) is 'accurate' i.e. correctly describes the relevant situations it covers; and iii) is 'parsimonious' i.e. different values of the cause-variable do not yield the same value of the effect-variable.

In this companion article, I discuss some potential applications for theories of proportionality (§2), and the main challenges they face (§§3–4).

2. Applications

2.1 Autonomy

The epistemic and metaphysical construals of proportionality vindicate the idea that explanations provided by non-fundamental 'special' sciences like biology, psychology and economics have a kind of objective, non-pragmatic superiority over corresponding explanations conducted at the level of fundamental physics (Putnam 1975, Strevens 2008, Weslake 2010). Fundamental physical propositions involve too much irrelevant detail for high-level effects: including this detail is not only unnecessary but inappropriate, since it fails to identify what made the difference.[4] Consider:

1. a) The peg doesn't fit in the hole because the peg is square and the hole is round.
   b) The peg doesn't fit in the hole because of the precise physical configuration of the peg and hole.
   (Putnam 1975)

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[3] There are different ways of converting this into a (non-model-relative) relation between events, by looking at all corresponding models or by choosing some canonical model.

[4] Weslake (2010: 287) argues that it is not only the contingent details of the physical situation which are irrelevant but also the physical laws themselves, since many alternative laws are capable of supporting the same high-level patterns.

Intuitively, (1b) misses out on the simple and unifying high-level pattern exploited by (1a). This is captured (to some degree) by all the characterizations of proportionality outlined above.

The physical configuration is screened off by the shapes, since had the shapes been realized by a different physical configuration, the peg still wouldn't have fitted in the hole. Similarly, the precise physical configuration is not a maximally general sufficer, since the more general shapes which it realizes are causally sufficient for the peg's failure to the fit in the hole. Also, the physical configuration does not counterfactually covary with the explanandum: assuming that situations involving alternative configurations which realize the same shapes are relevant, these are situations in which the configuration is absent and yet the explanandum remains.

Finally, assuming again that situations involving alternative realizers of the shapes are relevant, no variable containing the physical configuration is connected to the explanandum variable via an accurate, exhaustive and parsimonious equation. For example, the equation which accurately and exhaustively connects the various precise physical configurations to whether or not the peg fits through the hole is spectacularly unparsimonious: many different configurations will yield the same result.

Woodward's later work, which drops the parsimony constraint, abandons the ambition of vindicating autonomy in favor of the view that "proportionality can *license* the use of coarse-grained variables, even if it does not *require* this" (2018: 248; see also 2021: §8.5). In response to the observation that the resulting notion of proportionality is best satisfied by citing fundamental physical causes, Woodward (2018: 240; 2021: 372) notes that the corresponding explanations are never available in practice (since we never know what the precise physical configuration actually is, or indeed what the precise physical laws are). Thus, on this view, the practically available explanations which best satisfy proportionality are always high-level.

2.2 Mental causation

In the wake of Yablo (1992a), proportionality has been thought to play an important role in solving the problem of mental causation: roughly, if mental causes are non-physical, how do they have physical effects?

One potential role for proportionality is to provide the basis for responding to the 'causal exclusion' argument, according to which mental causes are excluded by their physical/neural realizers. Consider:

2. a) The monkey's intention to reach caused it to reach.
    b) The neural realizer of the monkey's intention caused it to reach.
    (Woodward 2008).

Given a metaphysical construal of proportionality, it might be argued that causal claims like (2b) are false, since the realizers of mental states are too specific to cause actions. This would allow such actions to have mental causes without being overdetermined (Yablo 1992a, Shoemaker 2001, List & Menzies 2009, Raatikainen 2010, Zhong 2014).

However, these responses do not address versions of the causal exclusion argument which employ the notion of causal sufficiency rather than (difference-making) causation. According to these versions of the argument, even if lower-level physical sufficers are not themselves difference-makers, they still render higher-level mental events causally irrelevant. An adequate response to such arguments should argue that this exclusion principle is false. Proportionality could yet play a role here by forming part of a sufficient condition for causal relevance (Yablo 2003, Strevens 2008, List & Menzies 2009). It is worth noting, however, that it is one thing to argue that higher-level mental events are causally relevant despite the causal sufficiency of their physical realizers, and another to argue that the apparent overdetermination which results is unproblematic.[5]

As Yablo (1997) discusses, the causal relevance of mental content raises special issues, since (assuming semantic externalism) the corresponding intrinsic states are neither more general nor more specific. Thus, these intrinsic states do not prevent would-be semantic causes from being proportional (on a comparative approach). Yablo (1997, 2003) argues that semantic and intrinsic causes may each be 'local maxima' in the trade-off between proportionality and naturalness, with each including irrelevant detail which cannot be removed without reducing naturalness.[6]

2.3 Absence causation

It is famously difficult to allow some absences to be causes without making too many absences causes. In particular, effects typically counterfactually depend on many absences which are not

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[5] For example, Bernstein's (2016: 36) 'Alarm' case suggests that causes operating at different levels may nonetheless overdetermine their effect.

[6] Yablo's (2003: 324) suggested definition of causal relevance for properties is not a plausible way of characterizing proportionality for events: for example, it entails that the bolt's snapping is proportional even if it fails to screen off the bolt's snapping suddenly (since, presumably, snapping suddenly is not more natural than snapping).

intuitively causes (Lewis 2000: 196, Schaffer 2000: 295, Menzies 2004: 145). There is, for example, the 'Queen of England problem' (Sartorio 2004: 322): the plant wouldn't have died if the Queen hadn't failed to water it.

Dowe (2010) observes that proportionality (on a metaphysical construal) prevents the proliferation of absence causation. Consider:

3. a) The Queen's not watering the plant caused it to die.
   b) No one's watering the plant caused it to die.

Applying Yablo's screening off characterization, *the Queen's not watering the plant* is not enough for the plant's death, since it fails to screen off *no one's watering the plant*: if someone other than the Queen watered the plant, it would not have died. Note that, as Bernstein (2014) points out, this relies on the questionable assumption that *no one's watering the plant* is a determinate of *the Queen's not watering the plant* in the relevant sense.

As Dowe observes, this solution has the serious drawback that it also excludes the gardener's omission: *the gardener's not watering the plant* also fails to screen off *no one's watering the plant*. Bernstein (2014) builds on this observation to argue that proportionality (in Dowe's hands) fails to solve the original problem. However, alternative characterizations of proportionality potentially avoid this counter-intuitive verdict. On the causal sufficiency approach, supposing that the fact that no one other than the gardener waters the plant is part of the 'background conditions' which are held fixed for the purposes of assessing sufficiency, *the gardener's not watering the plant* is causally sufficient for the plant's death, whereas *the Queen's not watering the plant* is not.[7] Non-comparative approaches likewise secure an asymmetry between the Queen and the gardener, on the supposition that hypothetical situations in which someone other than gardener waters the plant are not relevant, and that hypothetical situations in which the gardener waters the plant are relevant. The important work here will be in providing a principled conception of 'background conditions' and/or 'relevant' situations.[8]

The 'Queen of England' problem has been succeeded by the 'Prince of Wales problem' (Sartorio 2010). The problem has two parts: unwanted positive causes and unwanted negative causes. I only

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[7] Cf. Strevens 2008: 204 on 'explanatory frameworks'.

[8] A referee points out that some such resource could also be employed by the screening off approach. For example, the relation of determination could be evaluated with respect to some fixed background conditions, so that *no one's watering the plant* is equivalent to (rather than a determinate of) *the gardener's not watering the plant*.

focus on the latter here. Suppose the Prince ate some biscuits and got a stomach ache; had he watered the plant, he wouldn't have eaten the biscuits and got a stomach ache. Hence, his stomach ache counterfactually depends on his failure to water the plant. As Sartorio notes, proportionality helps here too — consider:

4. a) The Prince's not watering the plant caused his stomach ache.
   b) The Prince's eating biscuits caused his stomach ache.

Intuitively, (4a) is too general: the details of what the Prince did instead of watering the plant are relevant to his stomach ache. This is plausibly vindicated by the characterizations of proportionality above. On comparative approaches, the Prince's failure to water the plant isn't causally sufficient, and doesn't screen off the Prince's eating the biscuits (note that we are assuming that the eating determines the failure the water).[9] On non-comparative approaches, suppose that there are relevant hypothetical situations in which the Prince neither watered the plant nor engaged in any stomach-bothering activity. Then, since these are situations in which the Prince fails to water the plant but doesn't get a stomach ache, the Prince's omission does not counterfactually covary with the stomach ache, and the equation connecting it to the stomach ache variable is not very accurate.

2.4 Transitivity

Consider the following well-known putative counterexample to the transitivity of causation: a dog bites a terrorist's right hand, causing him to push the detonator with his left hand, causing a bomb to explode (McDermott 1995). Upon inspection, these 'mismatch' cases do not seem to succeed as counterexamples because there is no middle cause which is both caused by the first member of the chain and in turn causes the third member, and hence no genuine violation of transitivity. For example, the dog bite causes the terrorist to push the detonator with his left hand, but what causes the explosion is not the terrorist's pushing the detonator with his left hand, but his pushing the detonator (in any old way).

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[9] Sartorio (2010) argues that (4) can be developed in a way that is not addressed by screening off. In particular, suppose that had the Prince neither watered the plant nor ate the biscuits, he would have gone for a walk, and that would also have led to the stomach ache. Then, the Prince's omission does screen off his eating the biscuits: had he failed to water the plant but not ate the biscuits, he would still have got a stomach ache. (The Prince's omission now fails to screen off his either eating the biscuits or going for a walk, though this 'event' is arguably too disjunctive to be a determinate in the relevant sense.) Weslake (2010) concludes on the basis of this objection that (Yablo's version of) proportionality should be used in a psychological explanation for our causal intuitions rather than as a constraint on causation.

As McDonnell (2018) observes, a metaphysical construal of proportionality vindicates this kind of response to mismatch examples:

5. a) The terrorist's pushing the detonator caused the explosion.
   b) The terrorist's pushing the detonator with his left hand caused the explosion.

(5b) is overly specific — yet only the cause cited by (5b) is itself caused by the dog bite (since the dog bite is itself too specific to cause the terrorist's pushing the detonator). As the reader may verify, these verdicts are plausibly delivered by all the characterizations of proportionality mentioned above (granting — for the sake of non-comparative approaches — the assumption that there are relevant situations in which the terrorist pushes the detonator with his right hand).

As McDonnell notes, this treatment does not extend to all counterexamples to transitivity. Suppose that a boulder rolls towards a hiker, causing him to duck, which in turn causes him to survive (Hall 2000 discusses cases like this one). The hiker's ducking is plausibly proportional to his surviving: the hiker's either ducking or being such that there is no boulder rolling towards him seems too disjunctive to make the ducking overly specific. (See the discussion of the disjunction problem in §3.1.) These 'switching' cases — in which an initial cause selects one of two suitably distinct causal routes, each leading to the final effect — suggest that proportional causation is not transitive. Disjunctiveness is the key issue here: the problem arises from the fact that the initial cause can be made more general without becoming disjunctive, whereas the intermediary causes cannot be. (Switching cases also seem to violate McDonnell's proposed weakening of transitivity: if c is a proportional cause of d, and d is a proportional cause of e, then c is a cause of e.)[10]

2.5 Metaphysical explanation

Proportionality potentially extends to other kinds of explanation, especially metaphysical explanation, or its worldly correlate, grounding. I will be brief here, since there is almost no literature explicitly addressing this application.

The extension to other kinds of explanation is especially natural if proportionality derives from the nature of explanation itself (as opposed to that of causation in particular). Its application to the metaphysical case has perhaps been obscured by the obvious point that grounds at different levels do not 'compete'. For example, x's being scarlet and x's being red are each grounds for x's being colored. However, there is clearly also a sense in which grounds — or grounding-backed

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[10] A related application of proportionality, which I don't have the space to discuss, is in excluding deviant causal chains (McDonnell 2015).

explanations — contain the right level of detail to be 'difference-makers'.[11] On one hand, they contain 'enough' for what they ground. (Even 'contingentists', who hold that grounds needn't necessitate what they ground, acknowledge some sense in which this is true. Perhaps, for example, the grounds must necessitate given the background circumstances.) For example, x's being scarlet does not suffice to ground x's being a red square: the squareness has been left unaddressed. On the other hand, grounds lack superfluous irrelevancies. Grounding is widely acknowledged to differ from necessitation in that it does not obey 'Weakening': adding some irrelevant fact to the grounds does not yield new grounds (Fine 2012: 56). For example, x's being a scarlet square does not ground its being red: the squareness is irrelevant.

These features of ground — some kind of necessitation or entailment constraint, together with violations of Weakening — are plausibly universal to all explanatory or explanation-supporting relations. It is surprising, then, that none of the characterizations of proportionality mentioned above seem, at least prima facie, to capture the sense in which grounds are proportional. This raises the question of whether any of them can be generalized or adapted — and if not, whether we should seek some altogether new way of characterizing proportionality.

3. Spurious generality

3.1 The problem

Several authors have pressed the issue that the preference for generality is liable to recommend overly 'disjunctive' causes (McGrath 1998: 171-3, Williamson 2000: 83, Shapiro & Sober 2012: 90-1, Franklin-Hall 2016: 566-7). For example, in Yablo's (1992a) famous case of the pigeon who has been trained to peck at red objects, many other forms of stimulation would also lead to pecking. This counter-intuitively suggests that (6b) should be preferable to the 'overly specific' (6a):

6. a) The presentation with a red target caused the pigeon to peck.
    b) The presentation with a red target, or provision of food, or tickling of the chin, or electrical stimulation of the cerebellum, caused the pigeon to peck.
    (Franklin-Hall 2016: 566)

More broadly, without some constraint on generality, proportionality appears to recommend the disjunction of all propositions which would causally suffice for the effect.

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[11] For some relevant recent discussion, see Krämer & Roski (2017) and Hirèche (forthcoming). The arguments in Dasgupta (2014) illustrate the proportionality constraint on metaphysical explanation in action.

This 'disjunction problem' illustrates a broader issue: in many cases, proportionality appears to recommend causes whose generality does not make them genuinely preferable (Yablo 1992b: 420, Bontly 2005: 340, McDonnell 2017: §5.1, Vaassen 2022: §3.2). Consider:

7. a) Lucy's dropping that rock caused the sandcastle's destruction.
   b) The propulsion of some object with suitable momentum caused the sandcastle's destruction.
   (Yablo 1992b: 421)

8. a) Socrates's drinking the hemlock caused his death.
   b) Socrates's drinking some poison caused his death.
   (Bontly 2005: 340)

Intuitively, (7a) and (8a) may be both true and explanatory, and are, if anything, preferable to their 'spuriously general' (though apparently non-disjunctive) counterparts (7b) and (8b). (Examples like (7) illustrate a further issue: requiring proportionality threatens to remove all particular individuals from causes. Asides from being highly counterintuitive, this threatens to disconnect causation completely from moral responsibility, as Sartorio (forthcoming: §5) points out.)

The issue appears in different guises for different theories of proportionality. Firstly, it raises different challenges depending on whether one is adopting a metaphysical, epistemic, or pragmatic construal of proportionality: respectively, to explain why causal claims like (6a), (7a), and (8a) seem true, explanatory, and/or assertable despite the availability of their spuriously general counterparts.

Secondly, the nature of the challenge depends on whether one is adopting a comparative or non-comparative characterization of proportionality. On comparative approaches, the worry is that spuriously general events threaten to *exclude* their determinates: they screen off their determinates and they are more general sufficers. On non-comparative approaches, the worry is that spuriously general events threaten to *outshine* their determinates. If there are relevant situations in which the spuriously general event occurs but the determinate does not, then the spuriously general event counterfactually covaries with the effect whilst the determinate does not, and the equation which connects the spuriously general event to the effect will better combine the virtues of accuracy, exhaustivity, and parsimony than that connecting the determinate to the effect.

3.2 Solutions

One approach to solving the problem of spurious generality invokes 'naturalness' (Lewis 1983): the degree to which predicates (and, on Sider's 2011 development, other notions) carve nature at its joints. This approach assumes that naturalness can be extended to events (maybe via the properties they involve). One implementation, suggested by Yablo (2003: 326), is to trade off naturalness directly against proportionality.[12] Another, suggested by Jäger (2021: 577), is to trade off 'bad disjunctiveness' against proportionality, where this is defined via naturalness following Langton & Lewis (1998).

Invoking naturalness has been criticized as being overly 'metaphysical', 'mysterious' and 'heavy-duty' (Woodward 2016: 1056; Franklin-Hall 2016: 574; Blanchard 2020: 9). However, it is unclear that it is either epistemologically problematic or counts against ideological parsimony in a way which outweighs its fruitfulness. (Certainly, it does not seem more problematic in either respect than laws, counterfactuals, and other notions routinely invoked in accounts of causation.) Another concern is that naturalness may not deliver the required verdicts: in the case of (7a) and (8a), for example, it is unclear that the more general (7b) and (8b) are any less natural. Moreover, as Gómez Sánchez (forthcoming: §5.1) observes, naturalness seems unsuitably sensitive to fundamental structure. To illustrate this point, suppose that Yablo's pigeon has been trained to peck at red objects and also at yellow objects. Consider:

9. a) The presentation with a red target caused the pigeon to peck.
   b) The presentation with a red-or-yellow target caused the pigeon to peck.

Intuitively, the generality of (9b) is spurious since it cites a disjunctive cause. But now suppose we discover that red-or-yellow objects share (as a matter of necessity) some reasonably natural micro-physical structure. Suppose, for example, it turns out that all and only red-or-yellow objects reflect a particular kind of photon (though hold fixed that the pigeon's retina detects the frequencies of incoming photons rather than their kind). It seems that the newly discovered naturalness of being red-or-yellow would not undermine the spuriousness of events invoking this property.

Another approach invokes non-disjunctiveness, or 'cohesion'. Most straightforwardly, we might require that causes are cohesive. However, Sartorio (2006, forthcoming) argues that some

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[12] Yablo (1992b:423) also invokes the 'unity and integrity of the causal order': the idea that each event should have both many causes and many effects. Taking up one strand of Yablo's (1992b: §11) discussion, Touborg (2022), suggests that the problem of spurious generality may be addressed by relativizing proportionality to a domain of alternative causes.

causes/causal explanations are disjunctive. If so, instead of imposing a blanket ban on disjunctiveness, we might balance proportionality against degree of cohesion. This would allow for disjunctiveness in cases where there are no proportional cohesive candidates.

Cohesion may apply directly to causes, or — as Strevens (2004, 2008) proposes — to the processes/mechanisms by which they lead to their effects. For example, if the pigeon's brain processes dark shades and non-dark shades very differently, invoking dark redness may not seem overly specific, even if non-dark redness would also yield pecking.

The cohesion of a cause/process derives somehow from the similarity of its realizers. This invites two questions. Firstly, how is cohesion defined in terms of similarity structure? For example, is it some measure of average similarity, or is it connectedness(/convexity) — roughly, that any pair of points are connected by some (straight) path within the region? Secondly, what is the relevant space of possibilities, and where does its similarity structure come from? In particular, does it arise from fundamental physical structure (like that of phase space in classical mechanics), as Strevens (2008: 105) suggests? Or is it 'emergent' high-level structure (like that of color space), where this might derive, in part, from high-level laws involving the properties in question, as Rubenstein (forthcoming) suggests? A powerful reason to adopt the latter view is that high-level explanations — like those in psychology and economics — typically embrace multiply realizable causal processes. On this basis, Weatherson (2012: 472) argues that "what makes [high-level explanations] good is not the cohesiveness of their underlying physical mechanisms. It is, at least intuitively, the cohesiveness of the explanations from the perspective of the special science in question."

Finally, Woodward (2016, 2018: §4) suggests that the problem of spurious generality may be solved by attending to the principles guiding scientists' choice of variables. For example, with respect to (6), Woodward argues that these principles would license using distinct variables representing the various ways in which the pigeon may be stimulated, rather than 'lumping' them into a single variable. Among the principles he cites are that variables should be 'well-defined targets for single interventions', and that variables should be separated when they operate via 'distinct pathways' and are 'independently manipulable' (i.e. the value of one does not logically/metaphysically constrain the value of the other). If one's goal is to give an account of the worldly basis for our evaluation of causal claims/explanations, then one will want to supplement this proposal with precise criteria for individuating 'interventions' and 'pathways'.[13]

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[13] Woodward's approach here exemplifies his 'general project of "replacing metaphysics with methodology"' (2016: 1057). Blanchard (2020: §4) develops a more concrete interventionist proposal, based on the idea that causal explanations should specify which interventions would prevent the effect. In the absence of a more

4. Other problems

4.1 Spurious specificity

Typical causes do not nomically necessitate their effects. For one thing, some background conditions are usually required: the presentation of a red target would not yield pecking if the pigeon were blindfolded. As Jäger (2021: 583) and Vaassen (2022: 2827) point out, this raises a potential problem for proportionality: the conjunction of the ordinary cause with the required background condition threatens to outcompete the ordinary cause. For example, the presentation of the red target fails to screen off the conjunction of the presentation of the red target with the absence of the blindfold. One attitude we could take to this observation, as Jäger suggests, is that proportionality should not be viewed as a 'horizontal' selection principle, in Franklin-Hall's (2015) terminology: it does not select, out of the many simultaneous events that the effect required, which are causes and which mere 'background conditions'. Instead, it recommends a proportional 'whole cause' (where, following Mill (1843: Book III, ch.V, §3), the extraction of a salient 'contributing cause' might be left to contextual pragmatics). This approach requires some way of distinguishing the unwanted 'horizontal' cases from the 'vertical' cases — involving causes at different 'levels' – – in which we do want proportionality to apply.

In fact, a parallel issue arises when it comes to vertical selection. In particular, ordinary causes have atypical microphysical realizers. For example, as Vaassen (2022: n.13) observes, some ways of realizing the presentation of a red target involve the ejection of a rogue particle with enough momentum to kill the pigeon.[14] Let a 'normal' presentation of a red target be one which does not involve any such rogue particle. Consider:

> 10. a) The presentation of a red target caused the pigeon to peck.
> b) The normal presentation of a red target caused the pigeon to peck.

(10a) fails Yablo's (1997) 'enoughness' condition: the presentation of a red target fails to screen off the normal presentation of a red target (had there been an abnormal presentation, the pigeon would have been too dead to peck). On the causal sufficiency approach, causal sufficiency must accommodate suitable departures from nomic sufficiency, perhaps by invoking ceteris paribus causal laws or by making the normality of the presentation part of the 'background' conditions.

'metaphysical' ingredient, however, Blanchard's criterion threatens to count many ordinary causes as disjunctive (Rubenstein forthcoming).

[14] On the abundance of physical possibilities, see Albert (2015: 1-3).

Similarly, on non-comparative approaches, the presentation of a red target will not counterfactually covary with the effect (since there are situations in which it occurs without the effect), and the corresponding structural equation will be less accurate than that of (10b). One way of avoiding these results would be to somehow exclude abnormal presentations from the range of relevant possibilities. Alternatively, some further criterion might be used to privilege (10a) over (10b) despite the latter's greater degree of proportionality (with naturalness being one obvious candidate).

4.2 Piggybacking

A serious problem for non-comparative approaches involves cases in which some event intuitively includes irrelevant details but achieves proportionality by 'piggybacking' on the cause. Consider:

11.   a) The presentation of a red target caused the pigeon to peck.
        b) The presentation of a red target together with the existence of black holes caused the pigeon to peck.

Suppose that black holes are a suitably robust phenomenon, so that in all the relevant situations where the red target is presented, black holes exist, and in all the relevant situations where it is not both the case that the red target is presented and that black holes exist, the red target is not presented. Then (11b) will counterfactually covary with the effect as well as (11a), and its corresponding structural equation will just be as accurate. Yet, intuitively, (11b) should be counted as overly specific: the existence of black holes is doing no causal work vis-à-vis the pecking.[15]

As Gómez Sánchez (forthcoming) points out, the problem extends to the screening off approach. Consider:[16]

12.   a) The coin's size and shape caused it to make a certain sound when it hit the floor.
        b) The coin's value caused it to make a certain sound when it hit the floor.

Although the value fails to screen off the size and shape, this does not help since the size and shape do not determine the value in the relevant sense (it is possible for the coin to have the same size and shape and yet a different value). Moreover, since the connection between the coin's size and shape and its value is suitably robust (since it is supported by widespread and stable social and

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[15] This is a close variant of Yablo's (2003) problem of 'parasitic conjunction'.

[16] Kazez (1995: 83) uses a similar example to criticize counterfactual theories of explanatory relevance.

legal facts), the sound the coin makes counterfactually depends on its value: the nearest worlds where the coin has a different value are ones in which it happens to have a slightly different size and/or shape. This raises an important challenge for attempts to characterize causal relevance by supplementing counterfactual dependence with some counterfactual-based notion of proportionality (whether comparative or not). The causal sufficiency approach to proportionality, by contrast, appears well-suited to deal with this sort of case, so long as it can vindicate the intuition that there is a sense in which the coin's size and shape is causally sufficient for the sound whereas the coin's value is not (perhaps via a suitably fine-grained notion of 'causal law').

4.3 Redundant causation

As Yablo (1992a: n.60; cf. McDonnell 2017: §5.2) notes, cases of redundant causation — such as pre-emption and overdetermination — undermine proportionality as a constraint on causation.[17] Take (early) pre-emption: Suzy's throw shatters the window, but Billy would have thrown if Suzy hadn't. Hence, Suzy's throw fails to counterfactually covary with the shattering (the shattering occurs even in the absence of Suzy's throw), and Suzy's throw is screened off by some seemingly natural and non-disjunctive determinables (for example, if Suzy had touched the rock but not thrown the rock, the window would still have shattered). Meanwhile, the structural equations approach faces a dilemma. If the structural equation connects both Suzy's throwing and her not throwing to the window shattering, then it is not parsimonious: both values of the cause-variable yield the same value of the effect-variable. If, on the other hand, the structural equation connects Suzy's not throwing to the window's not shattering, then it is inaccurate: in many (if not all) of the relevant possibilities in which Suzy doesn't throw, the window still shatters.[18]

The causal sufficiency approach may yet avoid this problem if it can deliver the verdict that more general determinables like Suzy's touching the rock are not causally sufficient. However, even this approach struggles with ubiquitous cases of 'quantitative redundancy', in which some proper part of a cause suffices for the effect. Consider:

13. a) The sledgehammer's hitting the chestnut caused it to be flattened.
    b) Some half of the sledgehammer's hitting the chestnut caused it to be flattened.

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[17] Although, Sartorio (forthcoming: §4) suggests that in certain kinds of overdetermination cases, proportionality correctly favors a disjunctive cause.

[18] Perhaps this can be addressed by evaluating exhaustivity, accuracy, and parsimony whilst holding 'off-path variables' fixed at their actual values. This won't help with cases of overdetermination, however, and it makes the question of model-relativity even more pressing: which off-path variables should be included in the relevant model(s)?

(Mackie 1974:43)

(13b) appears to invoke a more general sufficer than (13a): the sledgehammer's hitting the chestnut seems to determine some half of the sledgehammer's hitting the chestnut in the relevant sense, whilst the latter seems causally sufficient for the flattening.[19]

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[19] See Strevens (2008: §6.24) for relevant discussion. Note that, in order to be sufficient itself, the sledgehammer's hitting the chestnut must necessitate some sufficient part of it hitting the chestnut.

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