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Can Causal Powers Cause Their Effects?

Abstract: Causal Dispositionalism provides an account of causation based on an ontology of causal powers, properties with causal essence. According to the account, causation can be analysed in terms of the interaction of powers and its subsequent production of their effect. Recently, Baltimore, J. A. (2022. "Dispositionalism, Causation, and the Interaction Gap." *Erkenntnis* 87: 677–92) has raised a challenge against two competing approaches, the compositional view (CV) and the mutual manifestation view (MMV), to explain what makes powers interactive – *the interaction gap*. In this paper, we raise the challenge of explaining what makes powers productive – *the production gap*. While Baltimore's verdict is tentatively favouring (MMV), we find both approaches wanting. Our conclusion is that Causal Dispositionalists should take Baltimore's and our critique seriously. Powers cannot cause their effects just by bearing the name "causal". To deserve their names, more metaphysical details are needed.

1 Introduction

Causal Dispositionalism (CD from now on) is the view that there are real, irreducible causal powers and that all cases of (efficient) causation can be explained in terms of the causal nature of properties (Groff 2013; Harré and Madden 1975; Mumford and Anjum 2011; *inter alia*).[1] Powers are understood as capacities, the possession of which has the effect of bringing about or *producing* a change in the particular that bears it or in the particular(s) toward which they are exercised (Harré and Madden 1975: 5; Ingthorsson 2002). Powers have this causal force because, in virtue of their causal nature, they metaphysically determine – or *tend* to determine – the occurrence of the effect – i.e. their manifestation.

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[1] For an account of formal causation in terms of causal powers see (Giannini and Mumford 2021).

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This non-contingent connection between the power and its manifestation is the simple essence of any dispositional theory of causation and the explanatory base for the causal regularities. (CD) can be further divided between those who think that manifestations equate to effects and those who do not.

The core tenet of the latter camp is that powers are causal components or parts, and each power is a (partial) cause for a causal contribution – its manifestation – to the composition of the total effect (Cartwright 2017; Molnar 2003; Mumford and Anjum 2011). Christen this, the Compositional View (CV). Some others see this approach as fundamentally misguided, still hostage of a tradition that looks at causation as a relation between cause and effect (see Heil 2012: ch. 6). What the view misses is that the possibility of a power's manifesting is always conditional on powers being *reciprocal* powers (Marmodoro 2013). According to these critics, causation occurs when two (or more) mutual manifestation partners produce the effect, viz. the manifestation. Causation is not a composition of causes and their isolated contribution but a dynamic, reciprocal causal process. This project, too, has notable supporters (Groff 2013; Ingthorsson 2002; Marmodoro 2007, 2013; Martin 2008; Martin and Heil 1999). Call this the Mutual Manifestation View (MMV).

Recently, Baltimore (2022) has argued that any coherent version of (CD) must answer two questions:

(Q1)   Why does a certain set of powers, and not another, interact?
(Q2)   Why do powers produce a certain effect and not another?

(Q1) and (Q2) are independent. The first concerns causal interaction: what explains that powers are non-contingently involved in instances of interactions. The second focuses on the cause-effect relation: what explains that certain interactions produce some particular result and not some other. Baltimore argues that (CV) and (MMV) interact differently with these questions. His verdict is that we shall prefer (MMV) over (CV) because the former, but not the latter, has the resources to explain the interactive nature of powers.

While Baltimore's verdict is based mainly on considerations related to (Q1) and on whether the two views can fill what he dubs *the interaction gap*, in this paper, we will focus exclusively on (Q2), that is, on whether the two views can fill what we dub *the production gap*.[2] In §.2, we explain the gap and why it is a problem for (CV). Our analysis agrees with Baltimore's verdict because, at scrutiny,

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2 Baltimore does, at some point, take into account how both views interact with (Q2), but his conclusion is largely based on how they score in respect to (Q1). Our aim in this paper is to assess the second question more in depth.

(CV) cannot fill the gap. Finally, in §.3, we examine (MMV). Here our conclusion diverges from Baltimore: (MMV) too cannot fill the gap.

2 Composition and Production

According to (CV), each power's contribution comes together with other powers' contributions; only then do they lead to the total effect. In dispositionalism's parlance, each *power part (token)* is a complete cause for its *manifestation* (*token*), and each manifestation is a partial cause for the resultant or *total* effect (Cartwright and Pemberton 2011; Molnar 2003; Mumford and Anjum 2011). The resultant effect is, *ipso facto*, what is referred to as the composition of powers. The view can be sketched using the following model:

$$P_1 .. P_n \qquad M_1 .. M_n \qquad e$$
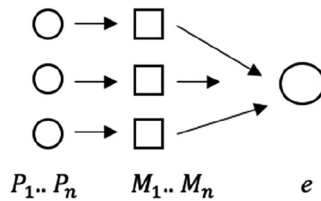
Put it simply, proponents of the compositional model share the intuition that an understanding of causation can be achieved not only by taking powers as *parts* but also by shedding light on how these parts are apt to get together to *produce* the effect. As Molnar puts it, "the effect depends on the *exact mix* of contributions by all the contributing powers" (2003: 195). The *production gap* for (CV) is the problem of offering an acceptable explanation for the connection between the composition of contributions and the effect based on the metaphysical resources that (CD) offers. We can understand the *production gap* compositionally in the following way.

$$x \overset{f}{\Rightarrow} f(x) \overset{g}{\Rightarrow} g(f(x))$$

Let us take f to be the function of each powers' contribution, and g the function from the total contributions to total effect – which is itself a power for the manifestation of another effect. Then, the result of the composition of contribution, $f(x)$, is sent to the resultant effect so that its being a cause for another effect can be expressed as the composite function $g(f(x))$.

We can set the domain of these functions as $\{x \in \mathbb{R} \mid x \geq 0\}$, and express that $\forall x(Gx > 0 \supset Fx > 0)$ and $\forall x(Gx = 0 \supset Fx = 0)$. Put in another way, if the contribution's values are positive, there is a function to a positive value of the

effect; otherwise, if the contribution's values are zero, there will be *no* effect despite there being a function for the effect. Let us interpret the "*exact mix*" as the set of values required for the total effect $g(f(x))$ to exist, in this case, $Rf \subseteq Dg$. The condition guarantees that all the input x from the domain of f for which $f(x)$ is not in the domain of g are excluded. For instance, if the input contributions are for $f(x) = -x^2$ and Rf is the input for $g(x) = \ln(x)$, the composed function $g(f(x))$ for $f(x)$ and $g(x)$ does not exist – because, for any x, $f(x) \leq 0$ and $g(x) \geq 0$.

It is easy to show that (CV) cannot satisfy the connection between the composition of contributions and effect with its internal metaphysical resources. According to (CV) and (CD) more in general, the essential connection between causes and effects should be explained in terms of the relation between causal powers and their manifestations. This relation is usually understood as Bradley internal (see Tugby 2016) because it is essential to the power to be connected or for, or directed to, its manifestation. The conjunction of facts about the existence of a power *a*, the existence of the manifestation *b*, and their internal relatedness *aRb* grounds the fact that there is a first-order causal pattern such that token power *B* is the physical manifestation of token power *A*. Based on the metaphysics, we know how to connect powers to their contributions via the relation between powers and manifestation. But what about the next step, from manifestation to the total effect? What composes are the single manifestations, so how can we move from the combined manifestations to the resultant effect? Prima facie, no internal resources are available to fill this gap. And if that is the case, the metaphysics cannot provide a satisfactory answer to (Q2).[3]

Some adepts of the (CV) have tried to look at the solution somewhere else. Cartwright and Pemberton, for instance, points out "this account of singular powers and their combination ... (...)... leaves the need for some account of composition" (2011: 110). To these days, it is Mumford and Anjum (2011) who

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3 At best, (CV) can offer a metaphysical story for $f(x)$, but the story to $g(f(x))$ is missing. Of course, the absence of such a story does not equate to the absence of any causal story that can be told with powers. It is easy to show that this instance of causation is rather unproblematic: $x \overset{f}{\Rightarrow} f(x) \overset{f}{\Rightarrow} (x)$. This function, which can be expressed as $f^2(x) = ff(x) = x$, is an instance where, given metaphysical story for $f(x)$, we can keep producing the original contribution input. We can interpret this as saying that you do not need extra powers to keep the contributions going, given a set of powers contributions. This is, however, only one causal story, where the same causes causally endure. Crucially, however, the causal story we are interested in is how we can get new causal facts as the product of other causal facts. It is this compositional story that begs for explanation. So, the problem is that without a story about $g(x)$, we cannot really conclude that having contributions in place suffices for the total effect. For this to happen, we need to make sure that there is a $g(x)$, an $f(x)$, and that their composition is exact, that is, to the effect that $g(f(x))$ exists.

offered the most detailed treatment of production as compositions. They propose that powers mix up to compose the effect is just what powers do, it is in their nature, and that how they do so does not require any further metaphysical explanation. This is tantamount to (a) taking a brute answer to (Q1): interacting is what powers do (see also Williams 2010), and (b) rejecting the claim that (Q2) must be answered by taking some further metaphysical resources. The core idea behind their main contribution – the vector model for powers – is that causes and effects are no distinct existences, nor causation is a relation between the two. Having contributions in place is "enough to bring about an effect" (2011: 86) because production results from contributions *plus* a principle, or rule, explicating how the effect is constituted. According to this reading, the mix is *always* exact, and no other story is needed because the connection between effect and contributions is such that "given a set of component powers there is *only one* result that can come about" (Mumford and Anjum 2011: 43). If Mumford and Anjum are correct, the inability to answer (Q2) metaphysically is not a symptom of a causal gap, only of a gap in our understanding. The vector model is proposed to bridge the second gap.

Nevertheless, we believe that this rules-of-composition proposal is unsatisfactory and that the view cannot answer to (Q2), hence falling prey to the *production gap*.

To see this, let us conjure a principle of composition that reflects what has just been described. Let us take the claim that contributions in place are "enough to bring about an effect", and that "given a set of component powers there is *only one* result that can come about" to form the *Principle of the Uniqueness of Power Composition* (UPC). (UPC) has it that (a) for a given pattern of causal contributions, no matter their distribution, they will produce the same effect; (b) a pattern of contributions *suffices* to produce the effect. These implications resemble two basic principles of extensional mereology: (M1) the Principle of Uniqueness of Sum and (M2) the Principle of Universal Existence of Sum. (a) is similar to (M1), namely that if U is a sum of $x_1 \ldots x_n$ and V is a sum of $x_1 \ldots x_n$, then $U = V$. Roughly speaking, if U and V are composed of the same elements, then U must be identical to V. The principle entails extensionality of composition since they only compose one whole for any sum of components (Varzi 2008: 3). Principle (M2) states that composing a collection is *just adding* to the collection, or more formally, for $x_1 \ldots x_n$ to compose U is for $x_1 \ldots x_n$ just to sum (Meirav 2004: 41). So, to speak of an existing whole is to speak of their parts existing. In the parlance of the vector model, this lines up with implication (b), i.e., the presence of the contributions is enough for the presence of the effect.

We can use the vector model to show that (UPC) yields the wrong result. Suppose we have three physical components, (a), (b), (c). Each is sharp enough

to have the causal power of piercing: they have the following token-powers (P_A, P_B, P_C). With the components in place, we can conceive of two wholes – U and V, say – with the same components but distinct arrangement.

The parts composing the two wholes share the same powers, so both in U and V component vectors are disposed to the same outcome (Figure 1). According to (M1), then, we might expect the two powers' wholes to be identical. Suppose (M1) holds for U and V. According to (UPC), adding the same vector-causes should entail that the resultant vector R is identical in both instances. Nevertheless, this is evidently not the case: as we can see in Figure 2, despite U and V having the same component powers disposed to piercing, the resultant vectors only act in this way in V, pointing in the very opposite direction in U. More formally: (x) if $R_U \neq R_V$, then $U \neq V$. Consequently (M1) does not hold: U and V have the same geometrical parts with the same powers, hence there is no difference in powers alone that makes the case that $R_U \neq R_V$.

According to (M2), the composition of powers just is their sum, and yet the totality of powers in U is not disposed in the same way as its components. Moreover, U differs from V because the former instantiates another power, namely, the ability to roll on flat surfaces. This power is clearly not proportional to the sum
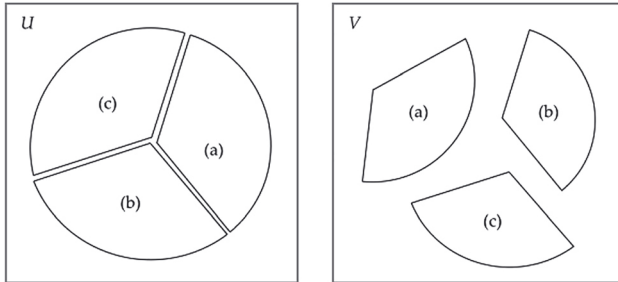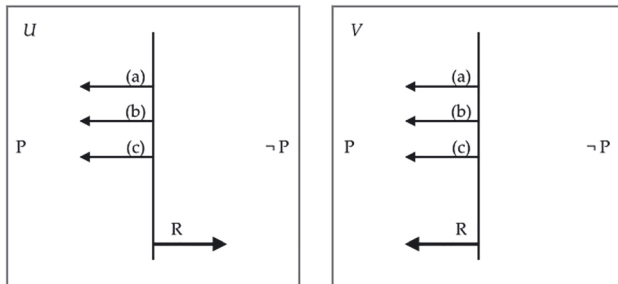

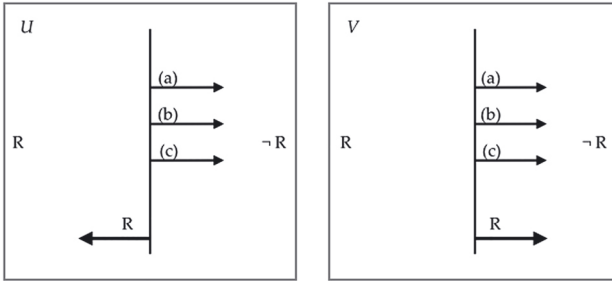**Figure 1:** Two wholes sharing the same components.

Figure 2: Vector models of U and V, in which components are disposed to pierce.

Figure 3: Vector models of *U* and *V*: in the latter components arranged in a whole are not disposed to roll, while in the former whole they do.

of the contributions, and even though both *U* and *V* are assemblages of the same component powers, *V* does not dispose toward rolling, as shown in Figure 3. The effect, then, cannot be equivalent to the sum of its contributions: (*y*) if $R_U \neq R_V$, then $\sum_{(A,B,C)} \neq A_{(A,B,C)}$.

Crucially, appealing to the tendential nature of powers and claiming that this step cannot be explained further sounds like cheating. For even if the step from the mixed contributions to resultant effect is tendential, the link between the former and the latter should be such that it preserves the non-contingent aspect of powers causation. We need an explanation of what non-contingently determines the *exact mix* that leads to the final effect, even if this *leading* is tendential because we need a complete causal story in terms of powers.

Friends of the rules-of-composition solution might, at this point, object that the way powers are arranged clearly makes a causal difference to the outcome. Cartwright and Pemberton, for instance, seek to combine causal capacities and a suitable *organisation* or *arrangement* (2011: 101). They claim that *arrangement* or *organisation* of causes has some causal influence in the production of the effect it provides the context in which powers exercise and dictate which effect is produced (Cartwright and Pemberton 2011: 94–96).

Assuming the causal import of *organisation*, it is no longer true that there is no difference in powers that makes $R_U \neq R_V$ true.[4] The two wholes now differ in their components, since their organisation should be counted as such – while *U* has a certain physical arrangement, *V* has another, different from *U*. This results in a causal difference that is grounded in the causal effect of the organisation, in such a way that while the resultant vector R_U disposes toward ¬*P*, R_V disposes toward *P*. Similarly, it is the organisation of the components in *V* that grounds the emergent effect of rolling, which cannot exist prior to (a), (b), (c) being organised

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4 I am grateful to Jennifer McKitrick for bringing this to my attention in private conversation.

in a relevant way. Hence, failing to satisfy (UPC) is just a symptom that classic extensional mereology cannot adequately capture structured wholes like causal composites (Koslicki 2018).[5] Like a ham sandwich is not just ham + bread + bread (Fine 1999: 63), composite of causes requires extra elements that account for their assembly. After all, the organisation has a prominent causal effect, and if causation is explained in terms of powers, we should expect powers to be part of the story of what makes an organisation causal.

Whether this is a viable solution to the *production gap* requires careful consideration. Consider the following question:

(Q1*)   Why do certain powers arrange and not others?

An answer in line with the previous example is that powers are location-sensitive (Molnar 2003), so when the bearers of powers are in close proximity, powers get in contact, and powers in close proximity are arranged into a structured whole. The idea is that, given some token powers (P_A, P_B, P_C) and their corresponding manifestations (M_A, M_B, M_C), these form a total cause in virtue of a relation r of proximity: $T_c = (M_A + M_B + M_C + r)$. However, organisation understood as spatial proximity has its limitations.

Firstly, in our example, U and V have different physical arrangements, but powers are in close proximity in both cases. If the organisation is a matter of proximity, it is not suitable to explain a causal difference between the two wholes. Secondly, if the organisation is spatial proximity alone, powers cannot be located close to one another unless they are *organised*. While this might be plausible for the ham sandwich example, it is clearly too implausible in the case of powers. It excludes the possibility of powers being in close proximity but not entering in any causal relation. The reverse is reasonable: powers cannot be organised unless they can be closely located. And yet, notice, this would only be true by stipulation. In fact, we are merely stipulating a relation r^* that acts as a principle of composition which is "rigid" – in the sense that gives form to the constituents (Fine 1999) – although non-extensional (or non-monistic) – because given two components a and b, $(a, b/r^*) \neq (b, a/r^*)$ (see Jacinto and Cotnoir 2019: 940) – and that, when it holds, spatial proximity holds too. Such relation r^*, which Fine calls Principle of Rigid Embodiment (1999: 65), does very little to explain why the resulting whole is different from a whole resulting from a classic mereological summation. And, in our case, we want to know what explains the fact that certain powers arrange, not merely how to model their arrangement. As Baltimore rightly points out, what is needed is some account of how and why powers *exploit* spatial

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5 More precisely, structured composites like the one under discussion violate Mereological Monism, the view that there is only one way of composition (see Lando 2017).

proximity (Baltimore 2022). On the other hand, if we claim that it is only the *right* powers that arrange given *r* or *r**, and so that somehow it is in the nature of powers that they organise to produce an effect, then the account is rendered superfluous, for *r* or *r** now does no significant work, and our answer to (Q1*) is simply that powers arrange as a matter of brute fact. To use a metaphor, it is not enough for powers to be in a bunch, but they need to be assembled properly. And like in a puzzle, the way they are assembled depends on their form. In the case of powers, the way powers arrange depends on their nature. To paraphrase Mumford and Anjum claim, having powers *arranged* is enough to have the effect.

We might or might not be happy with taking (Q1*) as brute. We admit we have no arguments against the claim that it is in the essence of power to interact *and* arrange in a specific way. It might very well be that the essence of each power contains a blueprint for how all powers fit together (see Williams 2010). But it also depends, secondly, on (Q1*) supporting a satisfactory answer to:

(Q2*)   Why a certain arrangement produces one effect instead of another.

One straightforward response is that the arrangement is a further constituent of the whole, so wholes with different arrangements would produce different effects. If the arrangement cannot be understood as *r*, perhaps it can be understood as a further power contributing to causal production so that a certain arrangement *R* in combination with the contributions of the powers produce one effect instead of another. More precisely, the manifestation of R does so, so that $T_c = (M_R (M_A + M_B + M_C))$. We have worries with this proposal too.

If the arrangement is a power, what is its manifestation? A natural answer is that the manifestation of the organisation power just is contributions that are organised in a certain way. Obviously, this will not do. Organisation only contributes causally to the production of the effect with its own contribution. However, if the production of the effect is contributions that are organised in a certain way, and if contributions so organised is the manifestation of organisation, then organisation alone suffice to produce the effect. Interpreted this way, the organisation's manifestation overpowers the causal contributions so that $T_c = M_R$. If, on the other hand, the manifestation of the organisation is non-relational, that is, it is not directly about causally organising the contributions, then we have that $T_c = (M_R + M_A + M_B + M_C)$. Yet, if the manifestation of the arrangement is another manifestation to be arranged with the others, the solution is clearly regressive.[6]

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6 As it is well-known, a similar pattern of regress is discussed by Aristotle in Metaphysics Z 17.

A more elegant solution is to adopt Mereological Potentialism (see Pfeiffer 2018) and an account of why a certain arrangement produces a certain effect in Aristotelian terms: distinguishing between *actual* and *potential parts* (Metaphysics Z17 1039a-103912). The solution does not account for structured wholes in terms of the causal effect of the arrangement as a component. Instead, it accounts for it in terms of parts specific to structured wholes and parts characteristic of unstructured sums. The formers are parts that are identity-dependent on the whole, or as Aquinas puts it, "the whole is present, as to the entire essence, in each" (1947). Thus, to use the puzzle metaphor, if each contribution is a piece of the puzzle when each of them is arranged puzzled-wise it is properly re-identified as a piece of the puzzle rather than a piece among the other in the heap. Its colour qualities, for instance, will no longer be seen simply as colour qualities but as a part of the image that the puzzle represents. Hence, an answer to (Q2*) is now available. If contributions are potential parts, and potential parts are identity-dependent on the structured whole, then no contribution can be a potential part of two wholes at the same time. Therefore, the collection of arranged contributions produces one effect instead of another because of the unique kind of structured whole it is at that time.

We believe that this solution is promising, especially given recent developments in non-extensional mereology (Canavotto and Giordani 2020; *inter alia*). Moreover, this solution is compatible with the *Principle of the Uniqueness of Power Composition* (UPC), so at least it is prima facie not in conflict with classical extensional mereology. From what we have just said, no two structured wholes can have the same potential parts. Moreover, it turns out true that having contributions in place is "enough to bring about an effect", and that "given a set of component powers there is *only one* result that can come about". Yet, this is not an option that sits well within the Compositional View. Because for the parts to be arranged is for the parts to be identity-dependent on the whole, the kind of structured whole the total cause is metaphysically determines the kind of arrangement the parts have. But notice that the parts here are the individual contributions, those that, according to Causal Dispositionalism, fix the identity of the powers (Bird 2007: Mumford 2004). So then powers themselves are identity dependent on the structured whole. If that is correct, it is then difficult to maintain that powers can exist in isolation and contribute with their individual contributions. These powers would be more in line with *actual* parts than with *potential* parts because both the power and the contribution are *independent* of other powers and other contributions. And since all the parts of a structured whole are dependent, a structured whole cannot contain independent powers/contributions. This Aristotelian solution makes much more sense if, instead of (CV), we adopt the Mutual

Manifestation View, according to which the idea of isolated powers and isolated contribution is off the table.

Taking stock: if we are right (CV) does not have the metaphysical resources to fill the production gap. The proposal of supplying the view with some account of composition is found wanting, and it is not clear whether the introduction of any structuring element can be deemed successful or even compatible with (CV).

3 Reciprocity and Production

As mentioned in §.1, proponents of (MMV) have a different take on how powers produce their effect and what the effect consists of. Advocates of (MMV) take manifestations as effects, eliminating any appeal to "contributions" as a middle-man ontological category. It is not the case that each power has its own individual manifestation. Instead, manifestations are *mutual,* viz. the product of the joint interactions of reciprocal powers, and each power can manifest differently given different reciprocal partners (see Heil 2012: 44–45; Marmodoro 2013: 224–225; Martin 2008: ch. 5). As discussed in the previous section, (CV) takes production as a compositional affair. As such, production is understood as primarily a synchronic affair: production is exact contributions structured in a relevant manner. On the other hand (MMV) emphasises the diachronic aspect of production. According to friends of (MMV), production is a processual affair. As Heil nicely puts it, "the effect is the outcome of a causal process, a causing, . . . which is a reciprocal, symmetrical, continuous affair" (2012: 44). It is reciprocal because it results from powers acting together to produce a collective effect (Ingthorsson 2002). It is symmetrical because the effect results from the powers working in concert. Finally, it is continuous because the effect obtains only so long as the causing does. Hence, production is a sort of *causal unfolding,* a process where the causal interaction occurs insofar powers hold together, and which terminates when the causal interaction is not taking place (see Marmodoro 2013: 228; Mumford and Anjum 2011: 124; 2018; Martin 2008: ch. 5).[7] According to (MMV), causes

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[7] Despite Mumford and Anjum's view can be safely classified within the (CV) camp, they too seem to subscribe to the view that causation is process-like. For instance, they claim that causation is process-like "in that one property (being solid) is replaced gradually by another (being dissolved)" in one continuous and dynamic process (Mumford and Anjum 2011: 124). Causes and effects form a continuous, where the cause somehow "perishes" while it moves from the start to the end of the sequence; causation is an unfolding process where there is gradually "less and less of the producing and more and more of the produced" (Mumford and Anjum 2018).

and effects are born together, or they are mutually actualised, in a continuous process.

$$P_1 .. P_n \qquad M_e$$
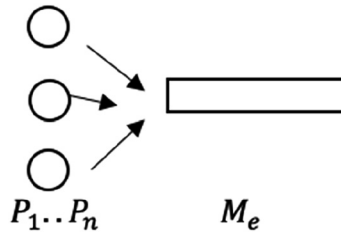
Baltimore argues that (MMV) scores better than (CV) because it has a straight-forward answer to both (Q1) and (Q2). Reciprocal powers interact almost by design, as it is part of their nature to do so. Moreover, they do not need an extra principle that governs their composition because their interaction is directed toward forming a collective result, viz., the mutual manifestation. If powers are reciprocal and capable of mutual manifestation, we can answer (Q1) and (Q2) with the metaphysical resources of the dispositionalist. We agree that prima facie is the case, but we believe that something more is needed to satisfy (Q2). In particular, we believe that (MMV) has its own production gap to fill. In fact, within (MMV) production is not just a matter of reciprocal work of powers but of the continuity of the manifesting. The *production gap* for (MMV) is the problem of offering an acceptable explanation *not only* of what triggers the continuous process of manifestation *but also* of what sustains it. In contrast to (CV), the internal metaphysical resources of (MMV) are more diversified, but ultimately, we argue, insufficient.

According to (MMV) simultaneity and continuity are central components of the dynamic nature of causation. Simultaneity is guaranteed by the outcome being temporally coincident with powers' manifesting themselves (Heil 2012). Continuity is guaranteed by each stage being the causal product of the stage that precedes it (Ellis 2001, 2002; Mumford 2009; Williams 2017).[8] Causal processes are thus dynamic because stages are internally connected – continuity – and there is no part of the process that does not involve change – simultaneity. Therefore, there is both individual and collective dynamicity.[9] Call this *full-blown*

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8 Notice that Harré and Madden seem to implicitly refer to a notion of dynamicity of this sort when they discuss generative mechanisms (1975: 131).
9 As Mumford and Anjum (2018) puts it: "A theory of causation suitable to biology must emphasize continuity and connectedness. We added some detail to this, explaining how causes can be temporally extended, but also simultaneous with their effects, and nevertheless also be able to form causal chains of a longer duration" (2018: 73).

dynamicity. In order to have production, full-blown dynamicity must be satisfied, and for full-blown dynamicity to be satisfied, simultaneity and continuity must be satisfied together.

Let us uphold one criterion while rejecting the other to see why this should be the case. First, we might try to uphold simultaneity and reject continuity. This first attempt can explain how, at t_1, a cause starts to transform into the effect; namely because two (or more) causes manifest together. Powers and manifestation, therefore, share the same temporal stage, and we have an initial degree of change. Hopefully, given that powers and manifestations will *always* share the same temporal stage, no portion of the process will be found that does not involve change. However, to have *continuous* change, we have to establish the connection between t_1 and the later stage t_2. Since the manifestation is not located in a successive stage of the sequence, no internal connection between t_1 and t_2 can be guaranteed. Moreover, since powers and manifestations will *always* share the same temporal stage, no part of the process will be internally connected. Stages are then only contingently related if related at all. However, this is not what friends of (MMV) claim. According to them, causation is process-like "in that one property (being solid) is replaced gradually by another (being dissolved) in one continuous and dynamic process" (Mumford and Anjum 2011: 124).

Second, we might try to uphold continuity and reject simultaneity. This second attempt can explain how causes at t_1 can be productive of another stage at t_2; namely, because the manifestation occurs at t_2, after the powers. Hopefully, given that powers and manifestation will *always* be present at subsequent stages, all stages of the process will turn out be internally connected. But given that at t_1 there is no manifestation, there can be no effect; hence there is at least one stage in which change cannot be found. On this account, manifestations will always occur only after the power, meaning that in no stage of the process we will find anything that is changing: each stage is *static* since no change can be found in it. This is not what advocates of (MMV) have in mind. For them, "the
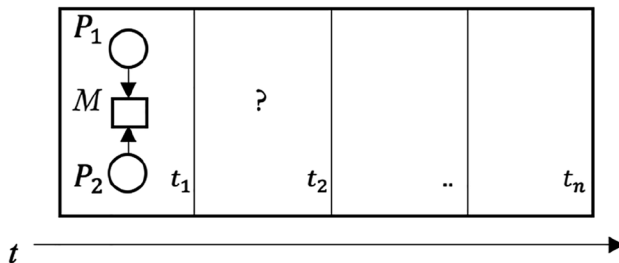

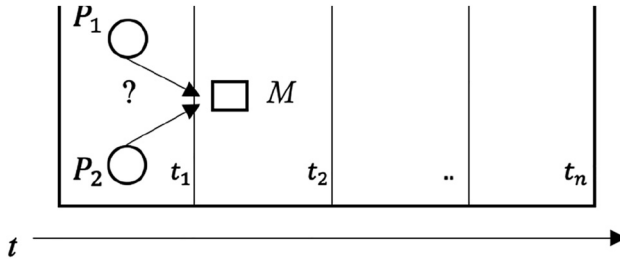**Figure 4:** Individual but not collective dynamicity.

Figure 5: Collective but not individual dynamicity.

part of a process is itself as active as the process itself (Mumford and Anjum 2011: 116).

If we are right, the first scenario presents a static process with dynamic parts: we, therefore, have individual but not collective dynamicity (see Figure 4). The second scenario presents a dynamic process with static parts: then we have *collective* but *not individual* dynamicity (see Figure 5). Therefore, we should satisfy simultaneity and continuity conjointly to get *full-blown* dynamicity and an adequate answer to (Q2) and fill the production gap. Unfortunately, we believe that such an answer is out of reach.

According to simultaneity, an effect is simultaneous with the cause. Thus, when we put an ice cube in the coke at time t_1, the effect is already there, at t_1. Note, however, that continuity implies that the effect cannot be at this same stage: this is because the cause must develop, that is, it needs to *perish* and be replaced with the effect. Were the effect present from the start, causation would not be time-extended in any sense: it would be simultaneous *and* instantaneous, which is not what the processual model requires. Nor does it help to say that the *total effect* is what we find at the end (Mumford and Anjum 2011: 122–123), for that would imply the amount of the effect we find at t_1 is just a *partial* effect. However, to talk about partial effects, we would need to shift from the processual to the *compositional* model, which admits the middle stage of causal contributions. Therefore, if causation is simultaneous, it *cannot* also be continuous. According to continuity, the process starts with the cause and transforms it into the effect. In the end, there is no more of the cause, and at the beginning, there is no effect yet. When we put an ice cube in the coke at time t_1 it continuously produces the effect until the end, the moment at which it "perishes", leaving the effect alone. Note, however, that simultaneity implies that the effect is already at the start of the process: the causes need to manifest from the start to give rise to a process. Were the effect present after the beginning, causation would not be simultaneous in any sense. It would be continuous, to be sure, *but not* simultaneous, and if we are correct in our analysis, this is not what the processual model requires (Nor,

for reasons given above, does it help to say that there is a tiny amount of the effect present at the beginning).

It seems we cannot satisfy *full-blown* dynamicity: we can hold continuity or simultaneity but not both at the same time. In fairness, this argument works only against some advocates of (MMV), like Ellis (2002), Harré and Madden (1975), and Williams (2019), who thinks that continuity is a matter of stages essentially following one another, thereby composing a process.[10] However, this is not the case for some others, like Mumford (2009), and Groff (2013).

According to Mumford, Groff, and Anjum, albeit we must find change in each part of the process (simultaneity), process' unfolding (continuity) is not achieved by stages being connected causally. As Mumford puts it, "if one tried to understand the process in that way, one would lose something of its dynamic and developing nature" (2009b: 28). Instead, the powers manifest by *becoming* the effect "as part of what it is to be those powers" (Mumford and Anjum 2011: 119). Thus, according to this approach, the process itself *is* the manifestation of the powers, and this manifestation is a continuous flow of change. Given that the manifestation is not composed of stages, the process itself is an "indivisible unity". Take, as an example, the process of baking a cake. We need certain ingredients, which initiate a process whereby causes gradually blend when combined with the others. Once the cake is baked, it is no longer possible to distinguish either the components or the powers: they gradually change into the effect in a continuous, unbreakable way. As Giannini (2021) recently noticed, the assumption of irreducibility is close to what the continuant theorists of processes call *homogeneity* (Mourelatos 1978; Steward 2013, 2015; Stout 1997, 2016):

(Homogeneity): if it is true that O was φ-ing between t_1 and t_2, then O was φ-ing during any subinterval between t_1 and t_2 (Steward 2013: 118).

For Stout, Mourelatos, as for Mumford, progressive stages of processes are essentially connected because, in each stage, *the same* process is developing (Mourelatos 1993: 386). So, for example, at each stage of photosynthesising, it is true simpliciter that *x* is photosynthesising, even if photosynthesising is made of different progressive stages. As there is no need for an extra metaphysical ingredient connecting the stages, continuity and simultaneity are mutually satisfied,

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10 Ellis is committed to the view that processes are composed of initial and final instantaneous stages, plus the acausal transmission that connects these "causal kind" events with "effectual kind" events (2002: 48; 2001: 52–53). Harré and Madden deny the independence of events or stages, presenting a theory of causation according to which causal powers are productive of successive state of affairs (1975: 4–7). Recently Williams has defended a similar view according to which "powers can be the mechanism by which persistence occurs" (2017: 145).

and so is *full-blown dynamicity*. If *full-blown dynamicity* is, so is (Q2), and the production gap is closed.

Giannini thinks that understanding processes as continuant is particularly important for understanding production as a process initiated by powers, along the line of Mumford, Anjum, and Groff. We agree. Dissolving, according to them, is a process that is the manifestation of mutual partners of the solvent and the solute. The causes will become the effect by acting together, resulting in the "sweet solution" (see Mumford and Anjum 2011: 121). At any stage of the process, one can find the causes acting together; hence simultaneity is secured. And again, at any stage of the process, it is the same dissolving that is occurring; thus, continuity is secured. Hence, the manifestation that is the dissolving between t_1 and t_2 is the same manifestation that we find during any sub-interval. Or so the story goes. However, we believe that this approach is of no use for friends of (MMV), and we can show that by using the same "sweet solution" case discussed by Mumford and Anjum (2011: 121) to motivate the view.

Although we agree that there is a sense in which it is the same process that occurs at every stage of the process, there is also an important sense in which this is not the case. Let us the dissolving be the φ-ing. Firstly, what it takes for O to φ-ing is for O to:

(a)   Have its solute molecules (sugar) separating from other solute molecules;
(b)   Have its separate solute molecules moving between the solvent molecules (water);
(c)   Have its separate solute molecules individually dispersing through the solvent (water).

Roughly speaking, our φ-ing is thus composed of three processes or progressive stages. These stages are progressive because for (c) to occur at t_n (a) and (b) need to occur at t_{n-1}. In fact, it is only when we progress from (a) to (c) that we have the "dissolving", that is, we have a process where a homogenous solution is forming. In this sense, we can understand "dissolving" as an accomplishment process where all molecules are individually dispersed (Hornsby 2012). Nevertheless, although O is φ-ing between t_1 and t_2, it is not the case that it is also *the same* φ-ing that is present in any subinterval between t_1 and t_2. Although it can be predicated that O is φ-ing between t_1 and t_2, (a) and (b) occur between t_1 and t_2 and are part of the process of dissolving but are *not* chemically identical to dissolving. Hence, the manifestation that is the dissolving between t_1 and t_2 is *not* the same manifestation that we find during any sub-interval. This is per se reason to think that the application of (Homogeneity) to the causal process initiated by powers is not as straightforward as one might initially think. But there

is another problem with looking at causal processes through this lens that would make (Homogeneity) undesirable.

To see this let us look at the properties of the progressive stages of the dissolving and of the dissolving itself. Progressive stage (a) is a process that requires energy to overcome the force of attraction between solvent molecules. Likewise, progressive stage (b) requires energy to overcome the force of attraction between solute molecules. These two steps of dissolving are then endothermic. On the other hand, in stage (c), energy is released due to the solute molecules forming a bond with the solvent molecules. This process is exothermic. The overall φ-ing can be endothermic or exothermic, but it is not so from the start. Whether the process is of one or the other kind depends on whether more energy is used to break the bonds in (a) and (b) or to form the bond in (c), with the total change of the φ-ing called *heat* of the solution. That is, it depends on the causal contributions *at each* progressive stage. These contributions together produce either an endothermic process, that is, a process that feels cold while φ-ing, or an exothermic process, that is, a process that feels hot while φ-ing. The problem for friends (MMV) that endorses (Homogeneity), like Mumford, Anjum, and Groff, is that they cannot explain why the process unfold in one way rather than another by appealing to a mutual manifestation being a homogeneous process. In fact, it is not the case that the φ-ing that is endothermic between t_1 and t_2 is the same φ-ing during any interval between t_1 and t_2. Whether the φ-ing between t_1 and t_2 is endothermic or exothermic depends on the contributions of each power involved. And if what explains why the process unfolds in one way or another is the individual powers' contribution, a satisfactory answer to (Q2) can only be given within the (CV) framework, and not the (MMV).

4 Concluding Remarks

Baltimore has raised an important challenge for anyone endorsing a theory of causation based on an ontology of causal powers. The challenge of explaining what it is that makes powers *interactive*. The challenge is significant, and the ability of the two leading contenders, (CV) and (MMV), to satisfactorily address it makes a difference for which of the two one must prefer. In this paper, we have raised another parallel challenge: that of explaining what it is that makes powers *productive*. While Baltimore's verdict is tentatively favouring (MMV), we find both accounts wanting. Our conclusion is that Causal Dispositionalists should take Baltimore's and our critique seriously. Powers cannot cause their effects just by bearing the name "causal". To deserve their names, more metaphysical details are needed. The good news is that, as both views were found wanting, no one is closer to securing this result than the other.

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