

# Dynamic all the way down

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## Abstract

In this paper we provide an analysis of dynamic dispositionalism. It is usually claimed that dispositions are dynamic properties. However, there is no exhaustive analysis of dynamism in the dispositional literature. We will argue that the dynamic character of dispositions can be analyzed in terms of three features: (i) temporal extension, (ii) necessary change and (iii) future orientedness. Roughly, we will defend the idea that dynamism entails a continuous view of time, to be analyzed in mathematical terms, where intervals are its constitutive elements, whose duration lasts as much as a certain change takes to occur (in support of i). Such changes are the necessary components for the flowing of time because we think there cannot be time without change, (thus supporting ii) and that the forward-looking feature of properties is what determines the direction of time (as per iii). The paper is structured in 5 sections. In the first section, we set the problem: we outline and criticize some dispositional theories that defend an unsatisfying notion of dynamism. In the second, third and fourth sections we defend each desideratum for a disposition to be dynamic. Finally, we draw some conclusions and consider potential future research.

## KEYWORDS

change, dispositionalism, dynamism, intervals, time, Zeno's paradox

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## 1 | INTRODUCTION

It is usually claimed that dispositions are dynamic properties. However, there is no exhaustive analysis of dynamism in the dispositional literature. While in the philosophy of time what is dynamism is quite clear,<sup>1</sup> some dispositionalists defend a different type of dynamism, one that does not mention temporal properties, like being present or past. Nonetheless, there is no clear understanding of dynamism in the context of dispositionalism, and dispositional dynamism thus remains a fuzzy view. In this paper, we propose a way to understand in what sense dispositional properties are dynamic, and so we'll provide an analysis of dynamism within a dispositional framework. We will argue that a dispositional property is dynamic if it satisfies three desiderata: (i) temporal extension; (ii) necessary change; (iii) future-orientedness. To make things clear from the beginning, by (i) we mean that time has to be interpreted as continuous, with intervals as its constitutive elements, intervals whose duration lasts as much as a certain change takes to occur. We are going to interpret this continuity in mathematical terms. (ii) means that there are no stimuli and manifestations without a change, and (iii) says that dispositions are essentially forward-looking properties.

To set the stage, we will outline the two main features of the dispositional theory we have in mind. Dispositionalism is the theory according to which possibilities are grounded in natural properties and their dispositions.<sup>2</sup> All modal truths are then grounded in the dispositional properties of actual entities. 'It is possible that the glass shatters' is true because the glass instantiates an irreducibly dispositional property: fragility. This is the main tenet of dispositionalism and it is widely endorsed. Some dispositionalists further claim that another tenet of dispositionalism is the dynamic character of dispositional properties.<sup>3</sup> Nonetheless, dynamism has never been properly analyzed by such dispositionalists, and this is what we will aim to do.

Let us begin by considering the current discussion with respect to this issue. Stephen Mumford (2009) takes dispositions to be intrinsically dynamic, and he does so by arguing against the account of persistence defended by Katherine Hawley: perdurantism. According to Hawley 'perdurance and stage theories share a common metaphysical picture—the world is full of very short-lived objects existing in succession' (Hawley, 2001, p. 42). This account of perdurance has that temporal parts are as fine grained as possible changes (more than merely actual changes) so that, eventually, these parts are fine-grained as time itself (Hawley, 2001, p. 49). Perdurantism, then, claims that entities are time indexed with respect to the indexing of their parts. Moreover, by claiming that they exist in a succession, the perdurantist is already assuming a temporal dimension, providing an analysis of dynamism that dissolves in such a succession of static temporal parts.

According to Mumford, the reason why dispositionalism and perdurantism are not a good match is that according to perdurantism, entities have temporal parts and each of these parts is *static*, *discrete* and *unchanging* (2009, p. 226). Mumford, on the contrary, argues that changes should be seen as extended properties (or processes)<sup>4</sup> and these, in turn, are taken to be intrinsically dynamic and as such 'should not ... be broken into static, instantaneous parts' (2009, p. 228). Perdurantism, on the contrary, seems to be forced to take the continuity of the processes as a non-supervenient relation holding on the static parts.

Hawley does indeed tell us that the continuity of the processes is a non-supervenient relation, because she cannot see how facts about processes of a thing could supervene on the facts about the static properties of the

<sup>1</sup>The A-theories are those which defend a dynamic view of time. Roughly, time flows and the present moment is somehow privileged, events acquire different temporal properties—*being future*, *present* and *then past*—as time passes.

<sup>2</sup>We use the terms "disposition" and "power" interchangeably.

<sup>3</sup>Mumford (2009), Mumford and Anjum (2011), Meincke (2020), Gozzano (2020), Roselli and Austin (2021).

<sup>4</sup>Also Perovic (2019) defends the idea that the temporal extension (and dynamism) of some properties must be accounted for. She indeed sets a taxonomy on the relation between properties and time. According to her, there are temporally extended properties (TEPs), properties had through times, to be contrasted with instantaneous properties (IPs), which are properties had at times. She makes the case for TEPs with a number of examples and then goes on showing that these can be categorically different.

changeless temporal parts of that process. A non-supervenient relation is thus an external relation that does not hold merely in virtue of its relata existing, rather in virtue of some further fact, over and above the intrinsic facts about the *relata* (Mumford, 2009, p. 229). So, as Mumford stresses, such a relation is extrinsic, and this would make the desired continuity disappear from the process. Instead, he argues, powers ontology has that the relation between parts of processes is not external but internal (i.e., intrinsic) to powers themselves.

Meincke (2020) also claims that dispositions are properties which are dynamic in character and that a process philosophy may be the best candidate to account for their dynamism. Indeed, in order to defend the dynamic essence of powers she claims that her '(...) take on powerful persistence is that dispositionalists ought to endorse neither perdurantism nor endurantism. They rather ought to be process ontologists and endorse a process account of persistence.' (2020, p. 21) However, she does not defend a fully developed account of such dispositional process ontology.

Both Mumford and Meincke take dynamism as a primitive notion somehow internal to powers. In so doing, they believe to have overcome the staticness that characterizes perdurantism. Nonetheless, we believe that although Meincke shifts the explanatory burden of the debate by taking a dynamic ontology as a default, she does not provide an alternative account of dynamic powers, and claims that an account of process persistence should be preferred without articulating the view in sufficient details. Mumford, on the other hand, faces the difficulty that the perdurantist faces. After all, the perdurantist argues that change is to be found in the variations of properties during time. But what makes Mumford's account different from the perdurantist position? Simply stressing that powers are primitively dynamic does not explain what makes them not static, transforming the issue into a linguistic quarrel. It seems to us that the move is an ad hoc one, that does not cut much metaphysical ice.

Roselli and Austin (2021) as well have argued for the dynamical character of powers, defending a renewed ontology. Taking steps from dispositions as multi-tracked,<sup>5</sup> Roselli and Austin underlie the importance of a unitary understanding of dispositions and in such a unified view, dispositions should not be conceived as caught by the collection of counterfactuals that are satisfied by them. Rather, it is the intrinsic nature of dispositions that accounts for the truth of a number of counterfactuals. Powers should be considered as 'functional mediators between input (stimulus factors) and output (manifestation states)' (2021, p. 14965). Consequently, the 'dynamical operator account', as they call it, says that to be a power is to be the performer of a specific causal role, locating 'the essence of a power not in what that power can do, but rather in how that power does what it can do' (2021). However, this functional reading may well be endorsed by a perdurantist as well, by taking functions to be executed by step-by-step 'static' processes.

Another way for making sense of dynamism in dispositionalism would be to devise a view on the track of the so-called 'at-at' theory of motion. According to it, motion, and change in general, is to be reduced to the different properties possessed by the same object at different times. Such a view, though, simply accepts that at each instant there is no real change, for change is the result of the object having different properties at different times. Clearly, one is left with the problem of how any change can occur, and how having one property at some time determines the property had at a later time. Arntzenius (2000) develops at length this problem by noting that even considering properties had at a time as properties belonging to a finite, or infinitesimal, development of states, the state of an entity does not determine the state of that very entity at a later time. So, one is left without a metaphysical solution to change and dynamism. We aim at developing an account of change that does not reduce to the mere appearance of a new property substituting a previous one, rather to a transformation (a change) of an object or entity having a property into that very object or entity having a new property at a later time. Roughly, it is analogous to the difference between a movement occurring in real life and one occurring in a movie by using a stop-motion technique. In the latter case, the movement is the

<sup>5</sup>They make this case in more elaborated terms, by establishing an analogy with the genetic cases of polygeny (and here the analog would be that one disposition is at the origin of more than one manifestation) and pleiotropism (several dispositions determining one manifestation).

result of changes occurring independently from internal changes in the entity and made up via photographic techniques.

Now, Mumford, Meincke and Roselli and Austin make evident the need for an essentially dynamic view of powers. But how can we understand such dynamism in more detail? Taking dispositions to be essentially dynamic, either by assuming dynamism as primitive or by taking it as intrinsically performed by a causal role, entails abandoning the need of providing an analysis of what such dynamism is and leaves the issue unsolved. Rather, we want to proceed with a positive analysis of dynamism in disposition, making clear what does it mean for a disposition to be dynamic. We agree with Mumford's aim against Hawley, and with the need to defend a dynamic character of powers. Nonetheless, this need is to be contrasted with the inappropriate reductive attitude of the perdurantist, according to which extended properties can be fully analyzed in terms of sequences of static instances. We then think that Hawley's account of persistence is the culprit for many difficulties that block a full understanding of dynamic properties, but we also think that Mumford and Meincke proposals are not detailed enough to fully account for dynamic properties,<sup>6</sup> because, beyond the critical part, they do not fully address an analysis of what dynamism is with respect to dispositionalism. We think that Roselli and Austin have taken a step forward, but, again, the performance of a causal role may be well accepted by a perdurantist.

In the next section, we are going to show that the static view defended by perdurantism leads to paradoxes and we set the basic elements to overcome them. Clearly, dynamism is particularly needed in case of continuous processes, since the discrete ones—say the passage of an electron from one quantic level to another—can be accounted for without it as well. However, as we will see, while the dynamic view could be of help in providing a satisfactory metaphysical framework for intrinsically discrete processes, it falls short if the processes are dynamic. A dynamic framework, instead, is at home in that case.

## 2 | DEFENDING TIME EXTENSION

Consider an object *O* whose temperature is rising over time. At each moment, *O*'s temperature *T* has a different value. Interpreted in static terms, the rising of *O*'s temperature pins down to the different values that *T* assumes in each of *O*'s temporal parts (*o*<sub>1</sub>, *o*<sub>2</sub>, *o*<sub>3</sub>, ..., *o*<sub>*n*</sub>). These differences are nothing but different properties that *O*'s temporal parts manifest. One may take these to be the same property having different values, but this entails assuming from the beginning a continuity in the process, which is something we challenge the static view can do. So, if at time *t*<sub>1</sub> temperature is 1C this is tantamount to *o*<sub>1</sub> manifesting property type *T*<sub>*n*</sub>; if at time *t*<sub>2</sub> it is 2C this is manifesting property type *T*<sub>*m*</sub> and so on. Some authors think that change, the rising of temperature, can be reduced to a sequence of static elements along the lines just described. As we said above, Hawley (2001) argues that an object whose temperature is rising can be understood not much as the change of the temperature of the object, rather as a sequence of object-time-slices, one of which has temperature 1C at *t*<sub>1</sub> and one of which has temperature 2C at *t*<sub>2</sub> and so on.<sup>7</sup> The nature of change would then be discharged over the transition from one object's temporal part to another, where a temporal part is distinguished from the next for a change in one of the properties of the object under scrutiny.<sup>8</sup> Basically, we have static objects with different properties somehow tied together through time (and this is just the lesson from temporary intrinsics by Lewis [1983]).

Given a static framework, the situation does not improve even if properties are conceived in dispositional terms; let us show why. The rising of temperature, interpreted dispositionally and statically, would be something

<sup>6</sup>We also wish to set aside those proposals favoring a revisionary ontology based on processes rather than dispositions (as in Meincke, 2020; Mumford & Anjum, 2011), as we are pondering on how to make sense of dynamism within a dispositional perspective.

<sup>7</sup>Change across time is like change across space: the different temperatures that the objects instantiate across a temporal interval can be 'analyzed' in the same way as the object having different temperatures in different (spatial) parts. (cf. Sider, 2001)

<sup>8</sup>Notice that such an account has another problem to face, that is, to explain how objects placed at different times actually are time slices of the very same continuant. We will not get into this issue now.

like that: at time  $t_1$ , by manifesting  $T_n$ ,  $o_1$  instantiates the dispositional property D1; at time  $t_2$ , by manifesting  $T_m$ ,  $o_2$  is being attributed dispositional property D2, at time  $t_3$ , by manifesting  $T_o$ ,  $o_3$  is being attributed dispositional property D3. It follows that nothing is rising. Rather, a plethora of properties are instantiated by the different temporal parts of an object, each with its own triggering stimulus or determined by the easiness of the object to manifest such properties,<sup>9</sup> and these are not dynamic properties. They can only be conceived as a temporal sequence over a temporal slice in order to make sense of (just an apparent) dynamic phenomenon. So, both the pure static non-dispositional view and the static dispositional view suffer from the same problem: they cannot account for change *in* the properties; they rather account for change *of* the properties. In both cases, there is not a dynamic property, rather a substitution of one property with a different one belonging to the same type (a temperature property with a different value). Such a reductive attitude, as the one described above when considering Hawley's perdurantist view, leads to paradoxes of the form made famous by Zeno.

Indeed, the logical structure of what we call 'the static option' can be treated analogously to Zeno's paradox of the arrow. According to Zeno, at each instant a flying arrow occupies a position, and so it is at rest at that position. Since a trajectory is considered as a series of positions in time, and time is a series of instants without duration, the arrow is not actually moving. Movement would then be just an illusion. Similarly, imagine the rising of the temperature as a scalar trajectory of different temperature values in time and time, again, as a series of continuous timeless instants. Since the instants are timeless, there would be no rising of the temperature at each instant. So, either there would be no rising of the temperature at all, contrary to the assumption, or an instantaneous passage, of infinite speed, from one value of temperature to the other. However, nothing can change instantaneously. So, both options are paradoxical and an explanation of how time and changing properties can be combined is still to be provided.

What is the way out of this paradox? The attempts at solving Zeno's paradox of the arrow are many, and in many cases they rely on mathematical subtleties developed well after Zeno posed the challenge. First, an essential step was the development of the infinitesimal calculus and Cauchy's demonstration that an infinite sum can give a finite result. Without getting into this issue (see Huggett, 2019 for a nice reconstruction and discussion), we have to consider how instants are conceived. Assume that the temperature rises in a linear way, to keep things simple. Assuming that time is a series of timeless, and so static instants,<sup>10</sup> entails assuming that these are fundamentally discrete instants. For, if an instant has no duration at all, that means that it is indivisible, so it is the ultimate discrete amount that can be considered. This, as we saw, brings us toward the paradox. However, it is possible to abandon such an assumption in favor of another one: time is continuous, and its constitutive elements are *intervals*. Clearly, one can have a continuous view of time also by considering instants and assuming that between two proximate instants there is a further instant. But these are static entities nevertheless, that bring us toward the paradox because there cannot be change at an instant. Vice versa, if the elements of time are intervals of decreasing length, but intervals nevertheless, the paradox can be solved. Here, each interval can be divided, and the result is two smaller intervals. And for each interval, there must be some change, no matter how minuscule the interval is. So, intervals are the measure of a change, something that cannot be done with instants. Whether the temperature is rising at an instant depends on whether it is rising in a finite interval that includes the instant in question. If the intervals are finite there is change in each of them (cf. Huggett, 2019). The dynamism that is looked for in dispositionalism, then, is to be found in taking intervals as the constitutive elements of time. In each interval, some change must occur, so properties have room for being dynamic.

How should we consider these intervals, though? Patrick Reeder (2015) presents a solution along the following lines. By using techniques in non-standard analysis developed by Robinson, Nelson and Lawvere (McLaughlin, 1994), Reeder considers these intervals as captured by *nilpotents infinitesimals*, numbers with non-zero values  $\varepsilon$  such that  $\varepsilon^k = 0$  for some positive integer  $k$ . So, these numbers multiplied by themselves

<sup>9</sup>As per Vetter's account (2015). In the rest of this paper, we may mention stimuli without, though, committing ourselves to the necessity of their presence. Potentialities or easiness of manifestation will do the job as well.

<sup>10</sup>Namely slices of time that cannot be further decomposed.

result equal to zero. These are placed at work in denying the third premise of a clear reconstruction of the Zeno paradox, that runs as follows:

- (1) Anything that is occupying a space just its own size is at rest. (2) A moving arrow, while it is moving, is moving in the present. (3) But in the present the arrow is occupying a space just its own size. (4) Therefore, in the present the arrow is at rest. (5) Therefore, a moving arrow, while it is moving, is at rest. (Lear, 1981, p. 91)

With respect to this argument, Reeder modifies premise 1, that now reads: '(1') Anything that is occupying some space just its own size for an extended period of time is at rest during that period of time' (Lear, 1981). For, it would be hard to accept 1 if it were not interpreted as 1'. Now, taking steps from White (1982), the crucial move that Reeder makes is denying 3.<sup>11</sup> This is reached by elaborating on the concept of *present*, handled by taking it to be the ultimate part of a continuum. Here non-standard analysis kicks in. In White's attempt, the present is an instant not represented as a point, rather as a 'monad' of that point, where this is the set of all points infinitesimally close to that point. However, rather than using monads, Reeder elaborates what mathematician Paolo Giordano calls 'rings', which basically are fields. The result, here very approximately abridged, is that instants are fields, infinitesimally small regions. How small? Big enough for the present to occur but not that small for there not being some change, a change that in the case of the arrow is such that the space that the arrow occupies in the present is larger *than* the size of the arrow itself. The field of values does not coincide with instantaneous value. So, back to the space metaphor of the arrow, the present allows for some extra space with respect to that that would represent the instantaneous position of the arrow; at the same time, such extra space is the closest interval to the space occupied by the arrow. The present is not a timeless instant, and this is crucial for understanding the role that intervals play in analyzing dispositions in dynamic terms.

The outcome is then the following: first, the minimal entities of time are intervals, and time is composed of infinitesimally extended intervals; consequently, the assumption that time is a series of timeless instants should be abandoned.<sup>12</sup> Time, then, is extended and continuous, and all its elements are changes occurring in intervals. So, whenever a property occurs in time, the property is a change of an object or entity occurring in an interval. In time as extended, not only dynamic but also apparently static properties manifest through intervals of time, because any effect takes time to manifest. Secondly, instantaneous properties, strictly speaking, are not possible because for a property to occur is for that property to occur in an interval, no matter how minuscule that interval is. Basically, taking a picture of the arrow will always result in a metaphysical blurry picture, and it is intrinsically blurry because, no matter how small the interval is, it is an interval nevertheless. Properties, then, are spatio-temporally extended as the objects or entities they affect are. Each temporal part of an object or entity has at least one property that changes during that temporal interval (more on this below). On the contrary, if time is a series of static instants, then there cannot be continuous properties for these need time to manifest. Having blocked the static option, and having defended our first desideratum, time's extension, to make sense of dynamism in dispositionalism we will now defend the other two desiderata (i.e., necessary change and future orientedness).

### 3 | DEFENDING NECESSARY CHANGE

Zeno's paradoxes are solved by taking time to be a series of intervals, rather than a series of static instants. So, the focus is now on intervals. How are intervals to be individuated? We want to maintain that intervals are such that

<sup>11</sup>The issue of occupying more space than one's own shape while in motion was a difficulty Arntzenius (2000) raised against the 'no instants' solution to the problem of instantaneous velocity.

<sup>12</sup>Something analogous is being said now on the concept of point in geometry. Since a point is an entity without extension, defining a line as the succession of points would give us nothing, leading to paradoxes. Point-free geometry is now being discussed.

they cannot exist without some change occurring. Being extended in time is equivalent to some change occurring. Basically, no extension in time without a change and no change without extension in time.

Now, part of this equivalence is trivial if considering that change entails time, as no one denies that. Quite different is to defend that time entails change. Famously, Shoemaker (1969) argued against the idea that there cannot be time without change. He imagined a tripartite world, where freezes occur in each part of this world, at different regular moments, say every 2, 3 and 5 years, and so we know that a total freeze occurs every 30 years. So, it seems intelligible to have a part of this world without any change, due to the freeze, but where time is still running, at least in the other parts. Consequently, we would have time without change. We think we can block this argument by considering a single world part. If time entails change, assuming time to be extended is equivalent in assuming that if there is no change then there is no time extension, hence no passage of time. So, if Shoemaker is right, he can deny the entailment by showing that we can make sense of a condition in which there is no change and still there is the passage of time.

Suppose we are in this world-part that is going to freeze. A moment before the freeze a causal process begins, say a ball is propelled toward the ground from a specific height. We know that all the times we tested this process the ball took  $m$  minutes to land, and we set a falling bodies law accordingly. Basically, we write the laws of nature, in particular so-called laws of succession, to forecast what will happen in the future, so in time. And the law says that from position  $P$  to  $P_1$  the ball will take  $m$  minutes. However, after the ball is released the world-part freezes, and the freezing lasts  $n$  minutes. After  $n$  minutes the world-part unfreezes and the ball lands. So, the ball spent  $m + n$  minutes before landing. But if this is the case, and we want to count time even if nothing has happened, then our law should be re-written. However, how can we rewrite the law? How many minutes should we add to  $m$ ? For suppose the freeze lasted  $2n$  minutes or  $3n$  minutes, would that change make a difference? Surely, for the law to hold, but how could we factorize these time differences into the law? It seems that for each possible difference in the duration of the freezing we should write a new law. But this is absurd for at least two reasons: first, the  $n$  minutes that we should add play no causal role and, secondly, we would have to explain why when the world is not frozen  $n=0$ . We do not count the duration of the freezing. So, no change entails no time duration contrary to Shoemaker's view.

It could be noted<sup>13</sup> that Shoemaker endorses a substantialist view of time: time is present even if no temporal entities are present. According to such a view, space-time points have primitive identity and since the parts, or the world, unfreeze after some time without any entities playing any causal role it seems that the cause of the unfreezing is played by time itself (Benovsky, 2012). However, substantialism faces an important objection, the so called 'hole argument' (Earman & Norton, 1987) according to which substantialism entails that two distributions of events—distinguished by an external and equivalent transformation—should be considered as different even if they are observationally and theoretically identical.<sup>14</sup> Here we cannot discuss the advantages or disadvantages of substantialism, as opposed to relationism, as view of time. At most, we can stress that some take substantialism and relationalism about time to be almost equivalent theses (Benovsky, 2010). What we want to stress is that a very powerful argument, the hole argument, looms on the concept of passage of time without any changes occurring.

A further indirect consequence of such an absolute condition is that in order to say that the ball takes  $m + n$  minutes to land,  $n$  must be determined from an absolute point of view. Assuming such a privileged frame of reference runs against special relativity, for the passage of this absolute time has to be considered with respect to a frame of reference, and this *ipso facto* would make it relative to it unless, again, conceding the first step of the hole argument (Norton et al., 2023). As a further side point: surely the argument is metaphysical, but in epistemic terms, how can we know that the world part has frozen for  $n$  minutes? Surely because we have counted time in the non-freezing parts. But counting is a way to have changes in time and is, again, relative to a frame of reference.

<sup>13</sup>We thank a referee for pointing out this very interesting issue. A first in-depth look at substantialism is in Hofer (1996).

<sup>14</sup>The origin of the argument can be traced back to Leibniz who pressed Newton and Clark on absolute space by asking what would change if East and West were switched. Leibniz insisted that this was a transformation determining an equivalence in space distribution; Clark, and the substantialists, are forced to say that space-time points have primitive identity and the switch resulted in a non-equivalent transformation.

Therefore, it would be better to discard the argument and accept that time entails change, thus defending our second desideratum: change is necessary. But we need to supplement the necessity of change by reflecting further on the metaphysics of intervals.

So far, we have argued that time is a series of intervals and that there is no time without change. It follows that intervals are the source of change. If time is nothing but intervals, intervals are composed of intervals all the way down. Notice that in each interval many changes may occur: a sphere may rotate and warm up, so interval and changes are not to be identified. But then we can ask: are changes composed of changes as well? Yes. Suppose that there is something like a minimum change, like a quantum of change. If that is the case, since intervals can be split into further and shorter intervals indefinitely, it would be possible to distribute that quantum of change in two intervals. In such a case, though, there would be intervals without change, hence time without change. But this runs against our previous argument. Therefore, we reject the idea of quanta of change, and we keep the idea that changes are composed of changes. So, each interval necessarily entails a change, as we intended to show. Hence, intervals are the sources of dynamism. In our view this is the crucial core of dynamism: there are no unchanging instants, because the smallest sections in which time can be split are intervals in which some change occurs.

How can we merge our reading of dynamism, crucially pivoted on necessary change, with the idea that dispositionalism is dynamic? Dispositions are conceived as properties directed toward manifestations, and in order to bring about such manifestations, dispositions need other dispositions to interact with, where all these manifestations occur in intervals of time. So, a disposition's dynamism is revealed by the manifestation of changes in the object that has the disposition. Since the manifesting is a change and it takes a time-interval to occur, no matter how small you consider these intervals, these are the minimal units that a manifestation needs to be what it is: an activated disposition. Manifestations are changes that occur in intervals and cannot be reduced to static components. Conceiving both the stimuli and the manifestations of dispositions in terms of changes in intervals, makes changes-intervals pivotal in understanding dispositionalism. Before getting into further details on dispositionalism, one may note that if manifestations are the way in which we understand changes we may run in a circle. For, if dispositionalism is dynamic, dynamism entails intervals and intervals entail changes then, if changes are taken to be the manifestations of dispositions, we seem not to have done a reductive analysis of dynamism in dispositionalism. In this respect, it is important to understand the relation between manifestations and changes: manifestations are a way to exemplify changes or are they to be identified with them? That depends on whether one is a moderate dispositionalist, one thinking that there are both dispositional and categorical properties, like Ellis (2001), or a pandispositionalist, one believing that all properties are dispositions. The point is: are there changes which are not the manifestations of one disposition or another? For instance, I can change a part of my car without this implying me having a particular disposition for that. But if changes occur as part of a disposition had by an object or entity, then that change is the manifestation of the disposition in question. Now, we can remain neutral on this, but we draw the proper metaphysical consequences: if pandispositionalism is endorsed, then you cannot give a reductive non-circular analysis of dynamism, for each change is the exemplification of one manifestation or another. If, on the contrary, a dispositionalist view that allows the presence of non-dispositional properties is endorsed, then the analysis is reductive. Let us now go into the details of dispositions and intervals.

If minimal units and intervals are equivalent, one may wonder how long they last. Since we said that intervals cannot exist without a change occurring, this entails that the duration of an interval is the same as the maximal change needed for an entity to manifest the disposition it is attributed to. For instance, the shattering of a glass lasts as much as its shreds fly away and land. So, changes and intervals go hand in hand with the disposition as caught by its manifestation: glass' fragility is caught by the shattering of the glass and the interval for a shattering is the flying and landing of the shards. One may note: the flying away of the shards are trajectories and these can be split into shorter intervals: are these the minimal changes of the shattering? No. Let us say that the glass is hit at  $t_1$ , it shatters and the shards land at  $t_n$ . In this amount of time, the shards' flying can be divided into temporal intervals, so how long does the manifestation of the glass fragility last? The manifestation of the glass' fragility lasts until the last shard has landed, so for the whole  $t_1$ - $t_n$  interval. This is

the interval for the change, a shattering, to occur. But surely that interval is not the one that occurs to each single shard to fly, because one shard could land before another. True. The fact is that while flying each shard is manifesting also other dispositions, for instance, one that has to do with its tendency to fly thus-and-so had it been propelled with energy and angle thus-and-so. So, while flying, each shard is manifesting more than one disposition, one as part of the manifesting fragility another as the manifesting of the kinematic of an object movement in the air, and these manifestations may partially co-occur or perfectly co-occur, if the shard that we are considering is the one that is the first in flying and last in landing, thus concluding the manifestation of the shattering of the glass. Indeed, entities can manifest more than one disposition at a time, and each disposition may have different intervals to manifest due to the occurrence of different changes. So, the interval for fragility to manifest could be longer than that for manifesting the disposition to fly if launched.<sup>15</sup> Notice, with respect to the solution to Zeno's paradox, what we are saying here is that the lasting of the intervals of the whole disposition are many and of different length for the disposition to manifest, while considered in their infinitesimal nature, each interval is larger than the shard it contains.

We take our account to hold also for those dispositions that do not need stimuli to manifest.<sup>16</sup> According to Vetter, for example, radioactive decay shows that no stimulus is needed for decay to occur. So, one may wonder how the dynamic dispositional view applies to a case that seems both dispositional and static. However, we should not consider a radioactive material which is not emitting as one in which no change is occurring and so no disposition can be attributed. For, when not decaying, a radioactive material is in equilibrium, and this entails another disposition, that of reaching and maintaining equilibrium thanks to opposing forces.<sup>17</sup> Again, objects may manifest more than one disposition at each time interval and each interval is such that it can contain some infinitesimal change.

So far, we have been arguing that dynamism is obtained (i) by taking time to be extended and continuous, where intervals are its constitutive elements; and (ii) by taking change as necessary, change that happens in these intervals which last as much as the manifestation of a given disposition needs to occur.<sup>18</sup> For what concerns dynamism this is all we need. But another condition is needed, though. Why? Because the two conditions individuated are compatible with reversible properties, that is, properties which are time invariant. However, another fundamental assumption of dispositionalism is that dispositions are forward-looking properties, namely, properties that are future oriented. And this third condition is to be represented in the dynamic nature of dispositions.

## 4 | DEFENDING FUTURE ORIENTEDNESS

Many physical events<sup>19</sup> are symmetric or time invariant: if we imagine them being filmed, the movie can run both ways without any loss of information or any difference in the laws governing or in the properties manifested by the event in question. Consequently, even if these events need time to manifest, they are not constrained in any direction. If they are not constrained, it seems that we cannot attribute the forward-looking (or future-oriented)

<sup>15</sup>This reminds the point of pleiotropism as discussed by Roselli and Austin.

<sup>16</sup>It has been frequently mentioned as a case that shows that the standard conditional analysis (SCA) of dispositions will not work. For, SCA usually takes dispositions to need a stimulus or trigger to manifest. Nuclear decay, at the opposite, is rather what we may take as a spontaneous disposition, one that does not need any trigger or stimulus to manifest, unless taking time itself as the trigger (Gozzano, 2020). This case, and other shortcomings of the SCA, have convinced some to abandon the idea that dispositions should be analyzed as in need of stimuli or triggers to manifest.

<sup>17</sup>This will surely remind of Mumford and Anjum (2011) approach to dispositions, taken as vectors of powers: if these are opposing and endowed with the same force, the equilibrium is reached. However, such equilibrium is the result of many subtle and continuous changes, so the dynamics is preserved in this case as well. See also Williams (2005) for a distinction between static and dynamic dispositions.

<sup>18</sup>One may wonder if these minimal entities are just the result of our epistemic or scientific interests in quantifying over events of a specific kind (shatterings, emissions, the expansion of the universe...). We rather think that these events are natural events, namely, the occurrence of perfectly natural properties, those that are or could be subsumed under some laws of nature. This means that you can epistemically cut an interval to its static instants; however, you cannot metaphysically cut an interval to get to its static constituents: they do not exist.

<sup>19</sup>We use 'event' in a general way and without a commitment to any metaphysical theory.

tendencies to the disposition bringing about these events. Since the forward-looking feature of dispositions is taken to be one of their intrinsic and main features (Mumford & Anjum, 2011; Vetter, 2015), it seems that if an event is brought about by a disposition, it cannot be time invariant.

Therefore, in order to argue that dispositions are dynamic we need to make a case of a disposition whose manifestation is not time invariant. Notice, we do not want to show the asymmetry of time head on; rather, more modestly we aim to argue that dispositions are a case of asymmetry in time (cf. Sklar, 1974).<sup>20</sup>

Consider again radioactive decay. Because of the instability of its nuclei, certain chemical elements release one or more particles. Decaying is future oriented because decay is asymmetric in that radioactive materials spontaneously release energy, but do not spontaneously absorb it. This feature makes decaying a property which is not time-invariant, and if being radioactive means being disposed to release particles, then radioactivity is a disposition which is future-oriented, as per one of the fundamental desiderata of dispositionalism.

Can we extend this analysis to other and more mundane properties? Generalizing, can we say that this is a feature of dynamism in dispositionalism? Consider fragility: to have the tendency to shatter—reading this property along Vetter's account (2015)—is quite different from having the tendency to reassemble. We are not stressing that usually or typically, or even necessarily, glass shatters but do not recombine. Rather, we are defending the idea that shattering and reassembling are different manifestations of supposedly different dispositions.<sup>21</sup> Indeed, we can imagine situations where glasses shatter and recombine or where glasses shatter and do not recombine. But can we imagine situations in which hit glasses keep their structure as a manifestation of recombination from a previous shattering?

One way to bring out this point would be to compare fragility with *pastgility*, a merely possible property. This is the property to be such that if struck at one time, then the object instantiating pastgility will be disposed to have broken at an earlier time. Clearly, pastgility is nearly identical to fragility, to the extent that the only difference between fragility and pastgility is their temporal orientation. Thus, we learn that it's a part of what it is to be the property of fragility, that the property in question be future oriented. This, and only this, differentiates pastgility from fragility. That being the case, the nature and identity of the disposition of fragility are temporally asymmetric and forward-directed in time. Pastgility, on the other hand, is backward-looking, so not a disposition since being forward looking is an essential feature of dispositions (Donati, 2018, p. 89).

Let us now consider the case with time invariant manifestations. Billiard ball A hitting ball B can be seen also as B hitting A if the film made out from their interaction is played at reverse. Here, in both cases, the dispositions at stake are the same, such as force and angular moment. So, these are perfectly reversible both in terms of mechanics and in terms of the manifestation of properties.<sup>22</sup> Not so in the case of a glass' fragility both in terms of reassembling and in terms of pastgility. Would this force us to exclude the classic mechanics cases as manifestations of dispositions? No. What it says is that the manifestation of a rolling by ball B must be preceded by its potentiality to roll and by some state of affairs or stimuli that have occurred before. As Vetter stresses in her Triviality thesis: 'where being F is a property whose possession would be grounded in the past, an object x will have the potentiality to be F if and only if the object is F.' (2015, p. 189) So, time invariant events can be marshaled among the dispositional properties because they occur in an interval as changes going toward some new state of affair or condition. A second reason for accepting these as *bona fide* dispositions is that there could be other dispositions occurring at the same interval, like the rising or decreasing of temperature due to friction, that could help to determine which is the proper direction we should take the movie to be playing. So, both fragility and pastgility satisfy dynamism, because these two properties are to be set into a time made up of intervals and such intervals are determined by changes. Fragility, being future oriented, satisfies also dispositionalism, since future-orientedness is one of its non-negotiable features. Consequently, fragility is a dynamic disposition, and we have an analysis of this, as we promised to deliver.

<sup>20</sup>The asymmetry of time seems characterized by three features: we have traces of the past but not traces of the future; causation runs from causes to effects; the past is closed whereas the future is open.

<sup>21</sup>Obviously, there are dispositions that have more than one manifestation, such as elasticity.

<sup>22</sup>In the billiard case, friction is also involved, which is a dissipative force, hence not time-invariant. Adding this property would solve the issue by fiat. Such an aspect does not change the overall point.

## 5 | CONCLUSIONS

What we have been arguing is that dispositional dynamism is to be analyzed in terms of (i) temporal extension, (ii) necessary change, and (iii) future orientedness. Once a property satisfies these three features, it can truly be said to be a dynamic disposition.

As a coda, we notice that one of the main advantages of the account of dynamism here defended, is that such an account can be adopted by different views of time. Indeed, it seems to be compatible with eternalism, the view that past, present and future exist; with the moving spotlight, according to which past, present and future exist, and the present is somehow privileged; but also with the growing block theory, the view that past and present exist, and future does not. It can be adopted also by a non-standard presentist, such as Hestevold, who defends a form of 'extended present', so a presentism that requires some temporal extension (see Hestevold, 2008). Roughly, all the theories of time that include temporal extension as a tenet are, prima facie, compatible with the view we have defended.

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