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ARTICLE

In Defence of Activities

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Abstract In this paper, we examine what is to be said in defence of Machamer, Darden and Craver's (MDC) controversial dualism about activities and entities (Machamer, Darden and Craver's in Philos Sci 67:1–25, 2000). We explain why we believe the notion of an activity to be a novel, valuable one, and set about clearing away some initial objections that can lead to its being brushed aside unexamined. We argue that substantive debate about ontology can only be effective when desiderata for an ontology are explicitly articulated. We distinguish three such desiderata. The first is a more permissive descriptive ontology of science, the second a more reductive ontology prioritising understanding, and the third a more reductive ontology prioritising minimalism. We compare MDC's entities-activities ontology to its closest rival, the entities-capacities ontology, and argue that the entities-activities ontology does better on all three desiderata.

Keywords Activities · MDC · Machamer, Darden and Craver · Capacities · Ontology · Metaphysics of science · Understanding · Minimalism

1 Introduction

Machamer, Darden and Craver (MDC) (2000) claim that: 'Mechanisms are entities and activities organized such that they are productive of regular changes from start or set-up to finish or termination conditions' (MDC 2000, 3). Illari and Williamson (2012, 120) offer the characterization: 'a mechanism for a phenomenon consists of entities and activities organized in such a way that they are responsible for the phenomenon'. We are in agreement with the other major contenders in the mechanisms literature that there are *two* constituents of mechanisms. Glennan (2002, S344) uses the language of parts and

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interactions, while Bechtel and Abrahamsen (2005, 423) write of component parts and component operations, but all maintain a twofold division.

The serious controversy concerning the constituents of mechanisms is over the nature of activities, interactions, or component operations. For MDC, what entities and activities are is best understood using examples, such as from the mechanisms of chemical transmission at synapses. Entities include 'cell membrane, vesicles, microtubules, molecules, and ions,' and are different from activities such as 'biosynthesis, transport, depolarization, insertion, storage, recycling, priming, diffusion, and modulation' (MDC 2000, 8). MDC go considerably further than either Glennan or Bechtel and Abrahamsen in making metaphysical claims for activities. Activities are not to be understood as mere features of entities. Instead, MDC hold a dualism of entities and activities: activities and entities are ontologically *on a par*. Since then, MDC have faced criticism of the notion of an activity (Woodward 2002; Bechtel and Abrahamsen 2005; Skipper and Millstein 2005; Tabery 2004; Psillos 2004; Torres 2009; Persson 2010). Nevertheless, the idea of an activity has interested many, and the *language* of entities and activities has been widely adopted (see for example Glennan 2002, 2005), although their ontological status has not been well-explored.

We find the activities-entities dualism to be an interesting novel approach worth developing, for reasons we touch on in Sect. 2. In this paper, our aim is preliminary: to clear away some initial objections, opening the way for its development. We distinguish three desiderata for ontology, where a desideratum is a motivating reason for doing ontology, so yielding the criteria for success. The first desideratum is that ontology should conform to the *description* of the world that is provided by science. In Sect. 3 we argue that such a descriptive ontology of science must include activities. This is the most permissive desideratum, and so Sect. 3 functions as an exploration of possibilities that it is the business of the more restrictive ontologies of succeeding sections to try to reduce in number. The second desideratum is that ontology should help us *understand* what things are. In Sect. 4 we explore this *understanding* desideratum, and argue that an ontology involving entities and activities does better on this desideratum than its closest rival, namely an ontology involving entities and capacities.[1] The third desideratum is that ontology should be as parsimonious as possible. In Sect. 5 we turn to this *minimalist* desideratum, and again argue that the entities-activities ontology does better than entities-capacities. Along the way, we show that these desiderata are in tension so that arguments put forward by proponents of one desideratum need not address objections put forward by proponents of another desideratum. To make progress in such debate, the desiderata must be made explicit, and argument shifted to the question of which desideratum to apply. We comment on relations between desiderata in the conclusion, Sect. 6, where we consider whether all three desiderata can be satisfied. Note finally that we do not attempt to replace capacities with activities. Our argument that the entities-activities ontology does better than the entities-capacities ontology leaves the open the possibility that a fully adequate ontology requires entities, activities *and* capacities.

2 What Activities Are

Machamer, Darden and Craver have two ways of saying what activities are. First, they make some general claims about activities, writing: 'Activities are the producers of

[1] We shall not discuss more distant rival ontologies in this paper—e.g., an ontology based on entities and laws.

change', (MDC 2000, 3f.) and, 'Activities are types of causes' (MDC 2000, 6). Second, they identify activities by examples: activities are the kinds of things that arise in examples of scientific work. In their work, MDC commonly proceed from examples much as we do below. This is important to their view, because they explicitly present themselves as following Anscombe, holding that there is only so much that can be said about causes in general, so that we have to look to examples instead (MDC 2000, 6, Anscombe 1975).

Since they follow Anscombe (see also Cartwright 2004), MDC do not attempt to give necessary and sufficient conditions for being an activity, and we do not either. However, their view has a problem if the two ways of specifying activities do not match. Without further argument, it seems unsafe to assume either that all things treated in an activity-like way by scientists will turn out to be kinds of causes, or that all things that are kinds of causes will be treated in an activity-like way by scientists.

In this paper, we will not begin with MDC's claim that activities are types of causes, working instead from examples of activities in scientific practice.[2] This generates a possible problem. MDC's claim that all activities are kinds of causes imposes a restriction on activities, whereas examples of activities seem less restrictive. Almost any verb, and many other pieces of language, could identify an activity: consider the spinning of all the spinning tops that are spinning in a clockwise direction. However, we will go on to suggest an alternative restriction. Activities are indeed vaguely defined and unrestricted. So are entities—consider the collection of all the left shoelaces in the world. However, as we shall argue, only certain activities and entities *occur within mechanisms*. Whether the activities so identified are also all kinds of causes is a question we will leave to further work.

We will begin our examination of examples with MDC's primary domain of concern, the biological sciences. There is a good argument from the successful practice of the biological sciences for the appeal to activities in the characterisation of a mechanism. Consider for example the following (non-exhaustive) lists of entities and activities gleaned from three major biochemistry textbooks' descriptions of the mechanism of protein synthesis (Adams et al. 1992; Voet and Voet 2004; Whitford 2005):

Entities DNA, operator, enhancer, promoter, RNA polymerases, repressor, activator, Watson–Crick base pair, covalent bond, replication fork, codon, anticodon.
Activities Trigger, binding, phosphorylates, modifying, wrapping, folding, cutting, catalyse, protect, opening, unwinding, supercoiling, breaking, inhibiting, stabilizing.

All three texts use almost all of the terms here, and many more, in providing an astonishingly rich description of the complex mechanism that makes proteins from strands of DNA. Thousands of entities are involved, but how many different activities are cited is also striking. And these activities are described and understood at a high level of abstraction from the particular kind of entities that take part in them. Note that the token activities are not abstract, but real. But their identification, description and study, at a level of abstraction from the entities that take part in them, is important to allow transfer of understanding of how one mechanism works to thinking about other similar mechanisms.

So for MDC activities are real, they are active doings that can be done by different entities, and they have an important role in mechanisms. Perhaps the most important aspect of activities is that they are dynamic. Unlike entities, capacities and properties—and other

[2] We reject MDC's claim that activities are the producers of change for reasons we have discussed in more detail elsewhere. In a nutshell, the reason is that some activities may not produce change, but maintain stability. For example, the activity of the homeostatic mechanism that maintains body temperature is to maintain a steady 37 °C, in the face of environmental variation.

common constituents of ontologies—activities exist only extended in time. If the world is dynamic, you might think there *must* be something dynamic in the most fundamental constituents of the world. You might think that talk of *dynamic systems* cannot be reduced entirely to talk of *static things* without loss, on any understanding of what that loss involves. We think this is the most forceful way to put MDC's point that activities are necessary because mechanisms are active not passive: 'Mechanisms do things. They are active and so ought to be described in terms of the activities of their entities, not merely in terms of changes in their properties' (MDC 2000, 5).

In this sense of being extended in time, MDC's activities are like Salmon-Dowe causal processes, which are—broadly speaking—the world-lines of objects which possess conserved quantities (Dowe 1995). Activities are not defined in terms of physical quantities, but in the terms of whichever science studies them, and they admit of a great deal of variation, as we will see. Activities seem to have much in common with Dupré's conception of a process, which also allows variation and is extended in time: 'Our view is that these problems reflect a more fundamental difficulty, that life is in fact a hierarchy of processes … and that any abstraction of an ontology of fixed entities must do some violence to this dynamic reality.' (Dupré and O'Malley 2012, 188–189.) However, Dupré has not developed his conception of a process significantly beyond a few such intriguing quotes in this and independent work, so it is impossible to say more at present.

We will examine more important differences between activities and the better known capacities shortly, but we can summarise some key differences here. Cartwright's view is that most general causal claims such as 'aspirins relieve headaches' or 'electromagnetic forces cause motions perpendicular to the line of action', are really ascriptions of capacities—the capacity to relieve headaches ascribed to aspirin, and the capacity to cause motions perpendicular to the line of action ascribed to electromagnetic forces. Capacities are properties, and they are real like entities, not abstract (see Cartwright 1989, 165, for argument). So both activities and capacities are real. However, activities are both occurrent and essentially extended in time, whereas capacities are not. Also, in an entity-capacity ontology, the relations between entities and capacities are strictly restricted—capacities attach on a 1–1 basis to single entities. In comparison, the arity of the activity-entity relation is unrestricted. Unlike a capacity in an entity-capacity ontology, an activity need not be a monadic property of some single entity, but can relate any number of entities.

In sum, an evaluations of the entity-activity ontology is worthwhile because activities have two distinctive features not present in some other ontologies: they are extended in time, and they have unrestricted arity.

3 A Descriptive Ontology of Science Must Contain Activities

Giving a descriptive ontology of science is to take what there is to be the things that science describes. This is the first of the three desiderata for ontology we will consider. Scientists spend a great deal of time figuring out what is in the world: if they find it useful to talk about certain items, when those items play a significant role in the practice of science, then a descriptive ontology places those items in the world. An ontology on this desideratum does not aim to be reductive or restrictive. It does not share the concerns of the traditional scientific realism debate: phlogiston and ether used to be in the descriptive scientific ontology, although they are there no longer. (We will also leave aside the issue of scientific realism in subsequent sections, since we will compare activities-entities dualism with an alternative that is also realist—an entities-capacities ontology.) A descriptive ontology is arguably the default scientific attitude. This approach imposes the fewest constraints of the three approaches that we will discuss, but it does impose *some* constraints. Scientists describing mechanisms do not talk about pixies and gnomes, so pixies and gnomes do not get into the constituents of the world.

This approach is not far removed from that of Quine (1948; 1969) or Wimsatt (2007). Consider Quine: 'Our ontology is determined once we have fixed upon the over-all conceptual scheme which is to accommodate science in the broadest sense…' (Quine 1948, 189). For Quine, broadly, if you need it for science, it must be in your ontology. Quine and Wimsatt are both primarily concerned with the existence of particulars such as a particular kind of entity with particular properties; we transfer a similar approach to thinking of *categories* of item in the world such as properties, capacities, or activities. We share with both Quine and Wimsatt the idea that ontology is in an important way *science*-driven. This is why this section remains of relevance to the succeeding sections that examine more restrictive ontologies. In this, we also follow such diverse current views as Ladyman and Ross's (2007) 'rainforest realism' and Dupré's (1993) 'promiscuous realism', in their method of proceeding from science, and also in their final view of multiple facets of the reality revealed by science, although of course there is a great deal in their work we do not emulate.

This is the best desideratum to begin with, because examining science is the best way to examine reasons for considering activities as candidates for any more fundamental ontology. This section will also continue to develop ideas about what activities are. Thus this section lays the groundwork for the discussions of Sects. 4 and 5, where activities are under the greater pressure applied by the traditional philosophical project of seeking a more reductive ontology. We will argue here that activities have an important role in the practices of the various sciences that use them, and that the activities described by such sciences are distinct from other obvious categories such as entities and capacities. On a descriptive ontology, this is all that is needed to take activities seriously. We will not argue here that activities are an irreducible ontic category.

We introduced activities using biochemistry, which is the domain MDC themselves use, and we will now look at other domains. Biochemistry is only one field within the biological sciences. Consider evolutionary theory. It is quite clearly concerned with entities such as genes, organisms, populations and traits. But it also studies, often abstracted away from any particular kinds of entities, *sub-mechanisms,* such as stabilizing selection, directional selection, and so on. Here, the fluidity of application of 'activity' and 'mechanism' is important. Mechanisms are decomposed into entities and activities. But activities in lower-level mechanisms are also frequently further decomposed into yet lower-level mechanisms. So at a different level of description a mechanism is an activity. We examine the constituents of natural selection extensively in Illari and Williamson (2010). There we suggest:

Activities Directional selection, stabilizing selection, disruptive selection, sorting, sexual selection, frequency-dependent selection, recombination, reproduction, meiosis, epistasis.
Entities Populations, organisms, cells, DNA, chromosomes, alleles.

Consider biology more widely. Biology as studied and taught has major divisions into anatomy, physiology and biochemistry. Anatomy is about the complex structure of entities, while physiology is about how such entities work. Biochemistry is a microcosm of biology itself—studying both structure and activity at a lower level. Note that the arity of the relation between activities and entities is fluid. The mapping of entities to activities can be unary, as in a bond *breaking*, involving no other entity; binary, as in a promoter *binding* to a strand of DNA; but it can also be 3-ary, 4-ary and so on (see Darden 2008, 964 and Illari and Williamson 2012). The activity of *transcription* involves DNA, the newly created mRNA, and various regulation and control enzymes, while more highly abstract activities such as *equilibrating*, or *osmosis* (Darden 2006, 277) may involve very many entities, of the same or different kinds, or be such that it is hard to decide on any very clearly defined entity that engages in the activity. This fluidity will be important later.

MDC's case is also promising for other disciplines. In chemistry, the activities or processes of an entity such as a molecule are divorced from the structure of that molecule.[3] And when chemists classify activities, they do so in abstraction from the actual molecules which take part in them. For an example of an activity, a S_n1 reaction is a substitution nucleophilic unimolecular reaction, whereas a S_n2 reaction is a substitution nucleophilic bimolecular reaction. It is clear here that the reactions, the activities, are described very much in terms of what happens—the substitution—with the entities involved described solely in view of their relevant properties.

Finally consider physics. Talk of mechanisms is important in astrophysics, and activities are clearly present. Consider: 'An important mechanism for producing X-rays from Solar System objects is charge exchange, which occurs when a highly ionized atom in the solar wind collides with a neutral atom (gas or solid) and captures an electron, usually in an excited state. As the ion relaxes, it radiates an X-ray characteristic of the wind ion. Lines produced by charge exchange with solar wind ions such as C V, C VI, O VII, O VIII and Ne IX have all been detected with Chandra and XMM-Newton [space observatories] …'. (Santos-Lleo et al. 2009, 998.) We can detect entities including: x-ray, ionised atom, solar wind, neutral atom, electron. Activities include: colliding, electron capture, relaxing, and radiating. (For more details, see Illari and Williamson 2012.)

It is clear from these examples that many sciences use talk of activities alongside talk of entities to describe systems. Among the things discovered by science are things that are not entities, but doings extended in time. They can be doings of a single entity, or of two, or of many entities. In their endless variation they are unlike Salmon-Dowe processes, but like Dupré's processes. In the unrestricted arity of their relation to entities, and in being extended in time, they are unlike capacities. Activities are prima facie constituents of the world on the descriptive desideratum. But there is more than this to be said. Scientists do more than merely *talk* about activities. Activities are vital in the kinds of theorizing we have described. We will argue that there is a reason for this.

MDC know there is more to be said. Scientists' talk of activities is not secondary to or derivative from talk of entities. MDC argue that activities are identified and described independently of the particular kinds of entities that take part in them. Machamer (2004) points out that even the *rates* of activities themselves are measured, which is clearly a description of an activity, not an oblique description of entities. MDC are absolutely right that the fruitful practice of the biological and other sciences depends on those practices regarding activities. Protein synthesis could not be properly understood without a wide understanding of, particularly, binding and catalysis, at quite a high level of abstraction from any particular kind of entity binding, or reaction being catalysed. The same is true of the other examples above.

[3] Note: chemists use the word 'mechanism' to refer to activities or processes, and the word 'activity' itself to mean an *effective* concentration—the molar concentration of a substance adjusted for the presence of other substances in the solution that make it less able to react. See for example: 'At very great dilution the hydrogen ion activity is equivalent to the hydrogen ion concentration $[H^+]$' (Dowes 1980, 39). However, the conceptual division of entity-like things from activity-like things is clear in chemistry despite the confusing difference in language.

MDC are absolutely right about this. But their point can be made even more forcefully. The key is the kind of *repeatability* that is observed in activities of the same kind. It is repeatability that explains why we quantify over and study kinds of activities. Consider a selection of the activities mentioned above: binding, inhibiting, catalysing; directional versus stabilizing selection; S_n1 versus S_n2 reactions; and radiating. Bindings of very different kinds of things show some common properties and consequences—two things become one. Directional and stabilizing selection show different characteristic features, and different causes and consequences, whatever population is affected. Whatever the entity is that is radiating, and whatever the energy is that it is radiating, radiating tends to follow a small number of set patterns. The token activities in the world are real, and describing them at these levels of abstraction from participating entities increases at least the predictive power of science.

Note that now we are talking about activities in mechanisms. Activities in mechanisms are those that are more repeatable and stable, involved in some way in the production of a worldly phenomenon, which is why they get into mechanisms. Clockwise spinnings of spinning tops do not constitute a stable enough activity to produce some kind of cohesive phenomenon, and so such an activity is not a part of any mechanism. The same is true of entities. Entities can be very vaguely specified and fragile. But the collection of left shoelaces in the world is not a source of repeatable patterns that matter to some phenomenon, so it is not part of a mechanism.

So while entities can be vaguely specified and unrestricted, as can activities, there are restrictions on which of these entities and activities occur as components of mechanisms. These components are the entities and activities that are relatively stable and repeatable and productive of some kind of phenomenon. That activities show this kind of repeatability, and that it is this that makes us bother about them, is the best way of interpreting MDC's claim: 'There are kinds of changing just as there are kinds of entities. These different kinds are recognized by science and are basic to the ways that things work' (MDC, 5). We are suggesting that MDC mean that we classify activities by features that ensure repeatability. And note, finally, that the same is true for entities. So entities and activities are included in scientific theorizing for the same kinds of reasons. To this extent, they have the same status. Further, due to a certain amount of stability and repeatability, activities in a mechanism have modal force (can ground counterfactuals about how the mechanism would operate in other circumstances) and so can explain how the mechanism makes a difference to the occurrence of the phenomenon that it is responsible for.

We would argue that these points constitute a strong case for the use of both activities and entities in characterising mechanisms in any descriptive ontology of the sciences. We may need to let entities, properties, capacities, and laws (or some kind of non-accidental generalizations) into such an ontology, since we are not aiming to be minimal or reductive, but we should have activities too.

Of course, this does not yet establish that activities are also constituents of a more reductive ontology. To many who would adopt a descriptive ontology, further metaphysical arguments about the ontological priority of either entities or activities don't matter. Those primarily interested in what a mechanism is—and uninterested in any further metaphysics—need read no farther. But MDC themselves have a stronger interest in the ontological status of activities. We agree with MDC that consideration of whether activities are among the more fundamental constituents of the world might tell us something interesting about mechanisms. We will examine approaches to a more reductive ontology in S4 and S5, disentangling understanding from minimalist desiderata, and arguing in favour of activities with respect to each of these two desiderata in turn.

4 Activities Do Better on the Understanding Criterion

We will move on to consider an ontology which aims to discriminate, among the items in the world, those that are more fundamental than others. We will argue that fruitful discussion of this requires explicit attention to the desiderata used to make such a discrimination. We will disentangle two possible desiderata: understanding and minimalism, dealing with understanding in this section, and with minimalism in Sect. 5. Some philosophers prioritise understanding and will be primarily interested in this section, while some prioritise minimalism and so will be primarily interested in the next section; although some philosophers may be concerned about both. We deal with these two considerations separately and explicitly to avoid the confusion that we argue results from allowing such desiderata to remain as unarticulated assumptions. Accordingly, we begin this section by examining arguments that do not articulate such assumptions, to show how fruitful debate is stymied in such cases.

Some of the debate over MDC's paper has occurred in isolation from explicit statement of such criteria. For example, Psillos in his 2004 points out that there may be cases where we get entities capable of engaging in certain activities, but the prevailing circumstances or laws of nature are such that they don't. He gives as an example: 'Chemical bonding could not exist without some entities having the right electronic structure' (Psillos 2004, 312).[4] Presumably atoms capable of bonding could exist without any actual bonding taking place. Psillos also says that he can't see how activities can determine what kinds of entities can take part in them—while presumably entities do determine what kind of activities they can take part in. He gives the example of *playing* (Psillos 2004, 312), which does not seem to set many constraints on the entities that can take part—although of course it does set *some*. A stone cannot play, which is because of facts about playing as well as facts about stones.

Psillos' central point is clearly right. There is a certain asymmetry in the ontological status of entities and activities, at least for some entities and activities. Machamer concedes this, saying that there is some entity-activity asymmetry in that entities act, but we can conceive of, or even actually experience, entities that are not acting. But we cannot experience (although we do abstractly conceive of) activities without any entities.[5] This is true of Psillos' example of chemical bonds and the entities that take part in them.

The important question to ask is what any such asymmetry establishes. We think it establishes nothing, because it is not addressing the right question. This asymmetry does not establish that talk about activities can be reduced to talk about entities. Comparing the status of entities with the status of activities is not the right comparison. That we want entities in our ontology is not currently in question. The question is what *else* we want in our ontology. So the right comparison is between the entities-activities ontology, and a competing ontology. There are several available: entities with their categorical properties, plus laws that determine how things with such properties interact, perhaps defined over possible worlds, with Lewis. Alternatively there are ontologies using entities and their

[4] Psillos originally phrases this as a conceivability argument: 'First, it's conceivable that there are entities without activities' (Psillos 2004, 312). We set this aside since conceivability is a notoriously unreliable guide to possibility.

[5] It might be argued that a perfect vacuum can engage in activities—e.g., sucking in matter. However, a perfect vacuum is arguably not entirely empty of entities, containing virtual particles (vacuum fluctuations) as well as dark energy.

dispositional properties, powers or capacities (Cartwright 1989; Shoemaker 1980, 1984; Mumford 2004; Gillett 2007, 2008).[6]

For the purposes of this paper, we set aside the objects-laws approach.[7] Instead, we compare MDC's entities-activities ontology only to their closest rival: entities and capacities. This will help clarify exposition. While the entity-activity approach clearly shares a lot with the entities-capacities—and indeed, the dispositions and powers—approaches, activities are a novel departure. Dispositional properties, capacities and powers are all broadly properties of entities, and to that extent adhere to a traditional description of the world in terms of objects and properties. So activities are something new, moving beyond the properties of particular entities. We anticipate that many of our arguments are likely to transfer to other members of the powers or dispositions camp, given the basic structural similarities of the views.

Psillos also compares activities with capacities. He argues that once capacities are in the picture, capacities are more fundamental than activities. He writes: 'it is *because* aspirin has the capacity to relieve headaches (a capacity which we take it to be grounded in its chemical composition) that aspirin engages in this activity, i.e., headache-relieving. If capacities are granted, then activities supervene on them. And this remains so, even if, from an epistemic point of view, we need to attend to the (observed) activities in order to conjecture about the capacities' (Psillos 2004, 313–314). This isn't clearly true. Nor is it clearly false. The problem is that such arguments are too isolated to be decisive. A theoretical background is required to assess them.

In general what is needed to decide whether entities and activities are both constituents in a more fundamental description of the world is a decision on whether talk of entities and activities can be reduced to talk of entities and their capacities without loss. But how are we to make such a decision? *Fruitful* attempts to discover a more basic ontology require explicit discussion of what loss establishes that talk of one thing cannot be eliminated in favour of talk of another. And the relevant comparison must be kept firmly in mind. In this case, the comparison is not between entities and activities, but between two complete ontologies: the entities-capacities ontology, and the entities-activities ontology.

We address two criteria for the relevant loss, *understanding* in this section, and *minimalism* in Sect. 5. On the former approach to ontology, the more basic constituents of the world are those in the ontology that best improves understanding and the fruitful continuation of science. It has much in common with a purely descriptive ontology of science, being thoroughly science-led, but is interested in the further question of which of the many things scientists talk about are more fundamental. There are of course different ways of spelling out 'understanding', and we lack space to examine them in detail. We are broadly inspired by the work of Henk de Regt: 'Scientific understanding of phenomena … requires intelligible theories, where intelligibility is defined as the positive value that scientists attribute to the theoretical virtues that facilitate the construction of models of the phenomena. Intelligibility is not an intrinsic property of a theory but rather a value projected onto the theory by scientists. It is a pragmatic, context-dependent value related both to the theoretical virtues and to the scientists' skills' (de Regt 2009, 595).

[6] There are also process ontologists such as Whitehead (1929) and Rescher (1996) who claim that everything is a process. They are very much in the minority and we put them aside to address those MDC call 'substantivalists', such as Cartwright.

[7] In Illari and Williamson (2011) we argue that the fact that a mechanism is intended to offer a *local* explanation of its resulting phenomenon makes the objects-laws ontology, which renders mechanisms non-local, undesirable.

There is a great deal more that could be said about ‘intelligibility’, so it can be seen that there is no single guiding rule, but a group of important and related reasons for theory choice. However, we have said enough to see that, on this approach, A is reduced to B only if we understand B better than A, or at least, A is often *not* reduced to B if we do not understand B better than A. So, for example, on this criterion one might argue that claims about this world cannot be reduced to claims about counterparts in other possible worlds. The reason would be that we understand even complex claims about this world better than we understand claims about other possible worlds. On the understanding criterion, items that we have comparatively little understanding of, like counterparts in other possible worlds, are less fundamental, derived from other better-understood items. Leibniz’ mind-like monads and Spinoza’s ontology of things as modes of substance might also be rejected on this criterion as too alien to our experience to be fundamental to ontology. Note that we follow de Regt in rejecting the mere ‘feeling of understanding’ as irrelevant: ‘Scientists prefer a more intelligible theory over a less intelligible one, sometimes even at the cost of some accuracy, not because it gives them a ‘feels right’ sense of understanding but rather because they have to be able to use the theory’ (de Regt 2004, 105). It is actually having the skills to use the theory that counts, not the feeling of having the skills to use the theory.

In the remainder of this section, we address the understanding criterion for ontology. On this motivation, an entity-activity ontology is better than an entities-capacities ontology for three related reasons. Firstly, capacities appeal to something opaque (capacities) to explain something transparent and comparatively secure (activities). Secondly, capacities lose or skew the real structure of what is going on. Thirdly, direct investigation of activities leads to great increases in understanding in the sciences. MDC make the first point and the third, but making them together with the second and against the background of this criterion for ontology renders the overall argument stronger, we maintain.

MDC originally make the first point that activities are more transparent than capacities: ‘However, in order to identify a capacity of an entity, one must first identify the activities in which that entity engages. One does not know that aspirin has the capacity to relieve a headache unless one knows that aspirin produces headache relief’ (MDC 2000, 4–5). In the simplest empiricist way, while both activities and capacities are real, activities are occurrent, while capacities are not. We observe token activities happening, while we infer the existence of capacities from the activities we observe. Psillos objects that this is a mere epistemic point, which shows nothing about any ontological status of activities. He is right about the argument as it stands, but MDC are getting at something more substantial. Machamer offers an additional conceptual argument for the priority of activity over capacity: the very concept of an entity having the *capacity to be involved in an activity* presupposes the concept of an *activity*. Conceptually, *x* is clearly prior to *the capacity to x*, and you clearly have to understand *x* itself before you can understand any capacity to *x*, rather than vice versa. Ascribing capacities presupposes ascribing activities. So on an understanding ontology, activity is metaphysically prior to the capacity to engage in an activity. This is something independent of a mere ‘feeling’ of understanding. Machamer puts it succinctly when he writes: ‘activity must precede potentiality’ (Machamer 2004, 30). Although Machamer does not further develop this point, it is a convincing reason for believing that activities are prior in understanding to capacities. In sum, on this criterion for ontology, we reduce A to B only if we understand B better; hence it makes more sense to reduce talk of capacities to talk of activities rather than vice versa.[8]

[8] Use of ‘capacity’ rather than ‘disposition’, ‘propensity’ or ‘power’ makes the point very clear, but this is not underhand. Any disposition or power is a disposition or power to do something in certain circumstances.

The second reason for preferring an entity-activity ontology is that it typically yields a more natural description of the world than an entities-capacities ontology. Recall that activities and entities allow unrestricted arity for the activity-entity relation. But capacities are strained in some circumstances. They make an ontology artificially skewed because they attach to entities—they are properties of entities.[9] In fact, each capacity is a property of a *single* entity. This is fine for some capacities, but is strained for others. Many of the activities that entities participate in are activities that require more than one entity. No single entity engages in *transcription*, which requires at the least DNA, mRNA, and regulation and control enzymes. Neither can a single entity engage in *osmosis* which requires at the least a great many entities of one kind, and a great many entities of a different kind. Such an activity, while real, can be described highly abstracted from many of the properties of the entities that take part in it. That abstract description is then used to work out what will happen with different entities or under different circumstances. Addressing activities directly, rather than via capacities, is the best route to increased understanding, to the unstrained use of the terms.

This point does not apply equally to all activities, since there are some that are not symmetrical and some that attach quite naturally to a single entity. Consider catalysis—the relation between the catalyst and the reaction catalysed is asymmetric. Or consider folding or breaking—a single entity can fold or break. But notice that it is *not* strained in these cases to consider the activity in isolation from the entity—particularly as so many different kinds of entities can catalyze, fold or break.

This leads us to our third reason for preferring direct rather than derived talk of activities. It is that direct investigation of activities is a successful strategy for improving our understanding of the world. This may be *because of* the second point that activities help generate a natural description of the world, but here we argue from the successful practice of science. Take osmosis or equilibrating as an example again. It removes distraction to study these activities in isolation, at a high level of abstraction from the entities that take part in them. In actual practice almost *all* of the properties of those entities are ignored. The study of activities such as these has been extremely successful, leading to concise general descriptions of extraordinarily complex phenomena. Talk of capacities might also be useful to science, of course. But put this point together with the point that activities are conceptually prior to capacities and yield an unskewed description of the world, and activities look more fundamental to understanding.

These three points together make a strong case for the entities-activities ontology as a better route to understanding than the entities-capacities ontology.

5 Activities Do Better on the Minimalist Criterion

The third approach to metaphysics is the traditional approach to the ontology of science—that the basic constituents of the world are those in the minimal adequate ontology. The

Footnote 8 continued
The thing done is conceptually prior to the disposition or power to do that thing. Note that our argument here is *not* that activities are actual and capacities merely potential, so we should have activities not capacities. Capacities and activities *both* have modal implications. Activities must be modal because an adequate ontology needs ways of describing not just how things *do* act but how they *will* act or *would* have acted under different circumstances. Psillos (2004, 314) can be interpreted as making this point.

[9] As are dispositions and powers, of course.

basic constituents of the world fit into an ontology that is small and highly unifying, and so are whatever the smallest, simplest description of the world says are in the world. This is quite different from the understanding criterion. With minimalism in mind it makes ontological sense to take as primitives items that make very little sense in terms of *understanding*—for example reducing certain sorts of claims about objects in this world to claims about what happens to things we have little epistemic access to, such as those in other possible worlds. The overall ontology being small and adequate is all that matters to minimalism. Understanding and minimalism are different, but legitimate, conceptions of the kind of loss that is not acceptable in reducing talk of one kind of thing to talk of another. Leaving such desiderata as unarticulated assumptions will only impede substantive debate, since an argument based on one will naturally come to different conclusions from an argument based on the other.

It is not easy to decide when one ontology is simpler or smaller than another. Quine makes this point (see for example Quine 1948). He distinguishes a physicalist conceptual scheme which talks of objects, from a phenomenalistic conceptual scheme, which talks of sense-experience. He points out that they each have their own simplicity. The physicalistic scheme simplifies our language by talking of external objects rather than complicated reports of sense-experience, and is physically fundamental, while the phenomenalistic conceptual scheme has epistemologically simple primitives. Of course, the idea that sense-experience is epistemically primitive is now outdated. As an alternative, Lewis (1973) distinguishes between qualitative and quantitative parsimony—between greater numbers of different kinds of things and greater numbers of things.

Clearly, comparing ontologies on size and simplicity can be complicated. However, comparing an entities-capacities ontology to an entities-activities ontology is more straightforward, because they share a great deal. Both ontologies have two components, both components are taken to be real, and both ontologies take entities as one of these components. MDC's overall ontology is anti-reductivist insofar as higher-level activities do not all reduce to the fundamental physical level, which makes it larger than a traditional reduces-to-physics ontology. But the comparison with the capacities approach remains fair since it also recognizes higher-level capacities as real. They both agree that higher levels do not vanish. So the important remaining concern is whether either activities or capacities are ontologically otiose, needlessly duplicating other elements of an ontology. We will argue that the entities-capacities ontology cannot be both adequate and *smaller* than the corresponding entities-activities ontology.

The entities-capacities ontology has to be large to be adequate. We need another example, since no single water molecule has the capacity to 'osmose'. Consider movement under gravitational attraction. All massive objects will each have indefinitely many capacities for movement due to gravity. Since capacities as originally presented are properties of single entities, capacities are at least doubled—each entity has the reciprocal capacity to attract all the others that have the capacity to attract it.[10] Further, the capacities ontology is explicitly potential, so any entity with mass has the capacity to move in a particular way for every gravitational field it might encounter—which includes all the gravitational fields it will never encounter. Because capacities are explicitly potential, you have, for example, the capacity to move in a particular way under the influence of a mass precisely double the mass of the entire universe, and precisely three times that mass, and precisely four times that mass, and all the masses in between. The capacities each object

[10] The powers literature now recognises this problem, along with the need for other cooperating entities, calling them 'mutual manifestation partners'. See for example Mumford and Anjum (2011).

has for movement due to gravity is of course a (small) subset of their multitude of other capacities for all the things each object might ever do. To provide an adequate descriptive ontology each object certainly has indefinitely many, possibly *infinitely many* capacities, almost all of which will never actually be realised.

This seems to create a truly needless proliferation. It is more parsimonious to use activities, which have unrestricted arity, to study and describe the activities, then to figure out how many different entities engage in them, and how. Scientists describe activities at the appropriate level of abstraction from the entities that participate in them. Things can be described in many ways, and descriptions do not add to the fundamental constituents of reality. As we have said above, scientists study activities at that level of description because that is the level that allows them to detect repeatable patterns. Scientists also describe entities in a way that allows us to see which activities they take part in, and which they do not, and study them at that level. With the two studies together, we can describe what entities do. An activity will, of course, be complex, and a careful account of their modal implications is required. Any adequate ontology needs to allow us to make claims about what entities will do, would do or would have done—modal claims—and more needs to be said about this. The activities approach does have the advantage that entities and activities are both actual, and what entities might do, could do or would do is secondary to what they do. Further, activities are successfully investigated by science, and more naturally grouped and investigated as activities rather than capacities artificially attached 1–1 to entities. Positive work on the modal nature of activities might be required, but activity-entity dualism is more ontologically parsimonious than the entity-capacities view, which needs endlessly to proliferate capacities to do the job of a single activity. The activity-entity ontology can do what the entities-capacities ontology does, with fewer items.

6 Conclusion

Activities are under-explored. Nevertheless their dynamic nature and the variety of complex mappings between activities and entities render them an exciting development in metaphysics. But their very novelty renders them unappealing to many.

In this paper, we have sought to clear away initial misgivings. There is a great deal to be said in defence of the entity-activity ontology over the entity-capacity ontology. Particular activities are indeed studied in many sciences. They are both conceptually prior to capacities, and simpler than capacities, which means they should not be eliminated from an ontology seeking understanding. They generate an unskewed description of the world, yielding a natural understanding that is conducive to the fruitful conduct of science. The entity-activity ontology is also more ontologically parsimonious than the entity-capacity ontology, so activities should not be eliminated from an ontology seeking minimalism.

Of wider philosophical significance, we have argued that without explicit statement of ontological desiderata, substantive debate over fundamental ontology will not succeed. We have not directly argued for one of the descriptive, understanding or minimalism desiderata over another. Readers are free to ignore one or more desideratum and consider only their preferred one. For example, it might be thought that understanding is a pragmatic, context-dependent notion, which bars it from relevance to ontology. On the other hand, even a minimalist ontology is supposed to be explanatorily adequate, and many argue that explanation and understanding are intimately linked.

Ultimately, one might be interested in all three desiderata. Indeed, we suspect that combining elements of each might well be the dominant, albeit unarticulated, approach in philosophy of science. One might take the descriptive desideratum as the starting point in terms of descriptive adequacy, and attempt to balance both the understanding and minimalist desiderata in narrowing down the fundamental components of reality. However, our arguments should at least suggest that entities-activities will still come out better than entities-capacities when these desiderata are combined, since they do better on each desideratum individually. In that respect, the desiderata are not in tension.

Further development is needed to make the entities-activities ontology viable. But we hope to have persuaded at least some not to cast it aside unexamined.

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