

Indeterminism and persistence

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Abstract

This paper aims at bringing together two debates in metaphysics that so far have been kept separate: the debate about determinism vs. indeterminism as *de re* modality on the one hand, and the debate about persistence on the other hand. Both debates significantly involve talk of things. We will show that working out a proper semantics for singular terms and an accompanying theory of things, motivated by considerations of quantified modal logic, can significantly further the persistence debate. We will use our semantic framework to give an argument in support of the endurantist (3-dimensionalist) position as the best theory of persistence.

Abstract (deutsch)

Das Ziel dieses Aufsatzes ist es, zwei metaphysische Debatten miteinander zu verbinden, die bislang unverbunden nebeneinander stehen: die Debatte um Determinismus und Indeterminismus im Sinne von Möglichkeit *de re* einerseits, und die Persistenzdebatte andererseits. In beiden Debatten spielt die Rede von Dingen eine wichtige Rolle. Es wird gezeigt, dass eine adäquate, durch Überlegungen zur quantifizierten Modallogik motivierte Semantik für singulare Terme und eine damit verbundene Theorie von Dingen die Persistenzdebatte deutlich voranbringen kann. Im Rahmen unserer Theorie geben wir ein Argument für Endurantismus (Dreidimensionalismus) als beste Theorie von Persistenz.

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1 Introduction

The metaphysical debate about the determinism or indeterminism of the world we live in (only one possible future, or many?), is hardly ever mentioned when it comes to the metaphysical question of how things persist (how a thing can remain the same through changes in the course of time). We believe that this points to a blind spot in the debate, rather than conceptual independence, and that a combination of both debates can lead to new insights for the question of persistence. We will argue that the connection should be forged via an appropriate semantics for singular terms that refer to things: the phenomena of persistence and *de re* modality call for the same semantical approach.

Prima facie, it doesn't seem too far-fetched to expect some interaction between the questions of determinism and persistence, as both questions are about the temporal development of the world around us and the things in it. To be precise, the question of determinism would also arise in a world (unlike ours) in which there are no things, but just, e.g., a single field with a changing state. We will however assume that we are dealing with a world in which there are things. On that basis, we immediately have a sufficient condition for indeterminism: if there is one thing in the world that can persist in more than one way (one thing that has open possibilities for its future), then the world is indeterministic. (Depending on how strongly one reads the assumption that we are dealing with a world of things, this condition may also be necessary for indeterminism.)

So, here is a first link: any unrealized possibility of a persisting thing (an unrealized possibility *de re*) is sufficient for indeterminism. We may safely assume that any of the normal things around us is a witness for indeterminism in that sense. Surely, e.g., the glass of water on the table before me can persist until tomorrow or be destroyed today: two incompatible possibilities for its future development, only one of which will be realized.¹

This link between indeterminism and persistence can hardly be denied, but it may also seem rather trivial.² It is less clear whether the fact of indeterminism (assuming, together with common sense, that it *is* a fact) also teaches us something

¹As one referee remarked, “can” has a variety of uses. In the example, “This glass can be destroyed today”, it is used in the sense of circumstantial modality as one form of root modality (see Kratzer, 1991). In contrast to the sentential operator form “It is possible that this glass is destroyed today”, which normally has an epistemic reading, (“It is compatible with all I know that ...”), circumstantial “can” modality has metaphysical import: it is modality in our world, based on real potentialities of things. See also Vetter (2010).

²To some it will also seem quite dubious—apart from the worry mentioned in note 1, there is of course also a significant debate about the status and the right analysis of *de re* modality. See §3.6 below for some comments.

interesting about persistence.³ Given that there are things facing more than one possible future development (and, to repeat, it is hard to deny that all things around us are like that), the following question arises: Which implications does this have for the persistence debate? Is the fact that there are numerous non-trivial *de re* possibilities for things, of any help in deciding the thorny question of *how things persist*?

Recall that in the recent persistence debate, there are three rival accounts, one three-dimensionalist theory, *endurance*, and two four-dimensionalist theories, *perdurantism* and *exdurantism*. According to the endurantist view, a normal thing is a three-dimensional entity that persists (remains the same through changes) “by being wholly present at more than one time”:⁴ probably the best sense one can make of this is: at each moment of its existence, it is present with all of its parts.⁵ Endurantism is the commonsensical view; the main challenge for endurantism, the problem of change, is to explain how one and the same thing can have different (intrinsic) properties (at different moments). The four-dimensionalist approach to persistence is motivated by the conviction that the problem of change is insurmountable. According to the perdurantist view, which avoids this problem, a thing is a four-dimensional entity that persists in the sense that there are different temporal parts, or stages, of the thing, at different times. These stages are themselves different things, and it is unproblematic that they can have different intrinsic properties. The normal thing itself is, according to that view, a four-dimensional “space-time worm”, which is not wholly present at any one time. Exdurantism is also a four-dimensionalist theory; however, in contrast to perdurantism, exdurantism takes the normal things we deal with to be stages and not space-time worms. Again, the problem of change is avoided as different stages can of course have different intrinsic properties. In a sense, exdurantism denies our normal conception of persistence: normal things according to exdurantism are just stages, and stages do not persist. Exdurantism, however, posits a temporal counterpart relation between stages to account for our normal talk of persistence, much like a counterpart-theoretic account of modality *de re*, and in this sense, it is still a theory

³As we will see, it will be enough for us if it is acknowledged that indeterminism is a (metaphysical) possibility: that already provides enough motivation to adopt a framework in which persistence can be represented in a novel, elucidating way.

⁴This phrase is Lewis’s, who attacks endurantism (Lewis, 1986, 202); it did not come up as an attempt at a useful positive characterization of endurantism. (See McCall and Lowe (2009) for relevant critique of Lewis’s framing of the debate, as well as for the following positive characterization of endurance: “An object *endures* iff (i) it lacks temporal parts, and (ii) it exists at more than one time.”) Still, the Lewisian phrase has stuck, so we will use it as well. It is however in need of elucidation. We aim at providing such elucidation below.

⁵Never mind the fact that things can lose parts—e.g., shed a hair—and still remain the same. See note 4 above for the artificiality of the slogan.

of persistence (see Sider, 2001).

Our main question will be: can the phenomenon of indeterminism, as witnessed by non-trivial *de re* modality, contribute anything to the debate about persistence? We will approach this question indirectly, from a semantic perspective: we will argue for a useful semantics for singular terms that does justice to *de re* modality, and we will ask about the impact of that framework if transformed to a temporal setting. It will turn out that all three mentioned theories of persistence can be modeled in our proposed framework, which we take to be good news in favour of the neutrality of our approach. In terms of metaphysics, we take this result to favour endurantism as the commonsensical view: in metaphysics as in dealing with other complex matters, it is good methodology to subscribe to the principle “if it ain’t broke, don’t fix it” (Lowe, 2009, 91), and so we should stick to what we started from.

Before we begin with our semantical investigation, we need to comment on another discussion in the vicinity of our subject matter, viz., the debate between a presentist A-theory of time and an eternalist B-theory.⁶ This is a thorny issue; there is even a substantial debate over whether there is a substantial debate between A- and B-theory at all (Meyer, 2005; Savitt, 2006). However that may be, it is clear that there is a significant difference at least in outlook on the status of a semantic framework, which is relevant for our enterprise. A truly presentist semantics, such as envisaged by Prior (1968), will have to treat semantics ultimately hermeneutically: our presentist natural language can only be elucidated by use of that same language (see Müller, 2007). Formal semantics is however mostly treated model-theoretically, implying a stance “above” the language to be modeled and the material it talks about; from such a stance, a whole semantic model, and thus, all of (space-)time, has to be accessible. Model-theoretic semantics is therefore essentially B-theoretic. In line with Prior, we acknowledge the power of model-theoretic methods in semantics, and we will proceed using a standard model-theoretic outlook, but we do not take this to settle the A vs. B debate in favour of B-theory; on the contrary, we want to let the A-theoretic position stand as a live option. (We do not even want to take a stance on whether ultimately there *is* a substantial issue between A- and B-theory.) Our reason for proceeding in a B-theoretic setting is purely pragmatic: it is simply much easier to formulate semantic assumptions model-theoretically.⁷

⁶We wish to remain neutral and not take a stance here as to whether there are implications between an A- or B-theory of time and the different views of persistence.

⁷An A-theoretic reformulation may well be possible along the lines of Prior’s idea of capturing B-theoretic model theory in A-theoretic terms; cf. his notion of “grades of tense-logical involvement” (Prior, 1968) and the ensuing development of hybrid logic, for which see, e.g., Blackburn (2000) and Bräuner (2011).

Here is how we will proceed. We start by discussing the phenomenological basis of our enterprise in §2. In §3, we lay out our semantic framework in detail, using mainly the phenomenon of *de re* modality and considerations of quantified modal logic as the underlying motivation. Then, in §4, we apply the framework to the persistence debate and give our argument in favour of endurance as the best theory of persistence.

2 The phenomena of persistence and *de re* modality

Both indeterminism in the sense of *de re* modality and persistence are phenomena involving *things*. What is that: a thing? There is much debate about this notion in metaphysics. While we cannot hope to resolve the issue, a discussion of the notion of a thing will certainly be helpful to motivate our semantic framework. We will therefore proceed with the aim of fixing a notion of a thing that identifies the right sort of entity for the phenomena of persistence and *de re* modality.

We use singular terms to refer to things. This cat, my daughter's cat Hannibal, is such a thing; I can refer to him, for example, by pointing to him now, or via the singular terms "this cat" (as used now), or "Hannibal". (I can also refer-to-him-and-stroke-him, which he likes.) Hannibal, the cat I'm referring to, wouldn't be a cat if he didn't have a certain history typical of cats—he was born of a cat, and he grew up from a small, blind newborn kitten to become quite a hunter. Hannibal has a history; he also has a huge number of *de re* modal properties, forming what we may call his modal profile. He's inside now, but he could be outside now as well; he left some of his food in the bowl, but he could have eaten it all. He could not, however, turn into a dog or a butterfly. He can persist in many different ways, but not in all imaginable ways. There are distinct *de re* possibilities open for him, and his persistence is constrained in many ways, given that he is a cat.

This is the phenomenological basis from which we will start. At least the central cases in which questions of *de re* modality and persistence make sense, involve proper things, things of a specific kind. We should be happy if we can lay out a theory of persistence that is able to handle these clear cases appropriately and that gives a (hopefully illuminating) verdict on less clear cases. It would be asking too much, however, if we were looking for a theory of indeterminism and persistence that is geared towards just anything we can refer to. In order to elucidate the notion of a (proper) thing further, we need to provide a useful semantics for singular terms.

3 Establishing a useful semantics for singular terms

3.1 Extension vs. intension

Many semantic frameworks, from Frege to Montague and beyond, distinguish between two aspects of pieces of language: their *extension* and their *intension*. It is commonly acknowledged, for example, that while the predicates “animal which has a heart” and “animal which has a liver” specify the same extension (they are true of the same animals), still they specify that extension in different ways; it could be, one thinks, that the extensions are different.⁸ According to Frege, who generalizes such considerations, even a sentence has an extension (a truth value) and an intension (a thought or proposition).⁹ Frege’s student Carnap proposes an even more general, regimented use of the extension-intension distinction. According to him, we should strive for a semantic theory in which each separate piece of language has an extension and an intension, where the intension is now a function specifying all possible extensions (the extensions in all possible cases). Carnap calls this “the method of extension and intension” (see Carnap, 1947, Ch. I).

Inspired by Carnap, Bressan (1972) suggests a fully symmetrical use of the extension/intension idea, which does away with the idea, still present in Carnap, that each piece of language has an extension *simpliciter*. According to Bressan, in many applications the possible cases (represented by a set of cases Γ) should all be treated as equally basic, as far as logic is concerned. Belnap has accordingly suggested to call that framework *case-intensional semantics*.¹⁰ The main idea is that each piece of language ξ has an extension $ext_\gamma(\xi)$ in each case $\gamma \in \Gamma$, and its intension $int(\xi)$ is simply the corresponding function from cases to extensions:

$$ext_\gamma(\xi) = (int(\xi))(\gamma); \quad int(\xi) = \lambda \gamma (ext_\gamma(\xi)).$$

At the ground level of the logical framework, there is no longer a suggestion that we must, or even should, distinguish a “real case” from other “merely possible” cases: the framework is fully symmetrical with respect to the cases. This will be important for our employment of the framework below.

⁸At this stage, the *epistemic* possibility of a difference in extension is enough to motivate the assumption of a difference in intension (broadly construed). In the framework of case-intensional semantics to be laid out below, it would depend on the details of the model under consideration whether the (technically specified) intensions of the mentioned predicates really differ or not.

⁹Frege’s notions of *Sinn* vs. *Bedeutung* do not coincide with the present-day distinction of intension vs. extension. Historically, however, they formed an important source of inspiration for the development of that distinction.

¹⁰For a nice exposition of the framework, see Belnap (2006); for further developments, see Belnap and Müller (2012). We follow the latter in matters of detail.

3.2 Singular terms: extension and intension

There is a substantial debate whether it is useful to apply the extension/intension distinction to singular terms; the most hotly debated question is whether we can assume that proper names have an intension in any useful sense. From the point of view of case-intensional semantics, this question has an easy answer: as far as logic is concerned, we should start with the extension/intension distinction quite generally; principles restricting the generality of the framework should be introduced, and argued for, at the level of science or metaphysics, but not at the level of logic or semantics. Like any other piece of language, a singular term α therefore has both an intension $int(\alpha)$, and an extension $ext_\gamma(\alpha) = (int(\alpha))(\gamma)$ in each case $\gamma \in \Gamma$. As a background assumption for the framework, there has to be, beside the set of cases Γ , a domain of extensions, D , so that $ext_\gamma(\alpha) \in D$.¹¹

3.3 Identity and predication

As a next step in giving an overview of the framework, it is useful to see how predication and identity statements are handled in case-intensional semantics. First, some pertinent terminology: we call a predicate P *extensional* if the question whether $P\alpha$ holds in a case γ , for α any singular term, can be answered solely on the basis of the *extension* of α in case γ , $ext_\gamma(\alpha)$. Predicates that are not extensional are called *intensional*; they look, as it were, beyond a given single case. The basic slogan for case-intensional semantics in this respect is “identity is extensional, predication is intensional”. That is, the basic semantic resources for predication allow for intensional predication, while the basic semantic resources for identity statements are purely extensional.

Put formally, this means that an identity statement “ $\alpha = \beta$ ”, with α and β singular terms, is true in case γ iff $ext_\gamma(\alpha) = ext_\gamma(\beta)$; thus, it is true or false solely on the basis of the extensions of the terms involved.¹² A predicate P , on the other hand, is treated as a piece of language with an extension $ext_\gamma(P)$ in each case γ , and a corresponding intension $int(P)$. What is the extension of a predicate? There are two obvious choices. If one wants predication to be extensional, as in first-order logic, then one will assign a subset of the domain D as the extension of a one-place predicate: $ext_\gamma(P) \subseteq D$. P then applies to α in case γ iff $ext_\gamma(\alpha) \in ext_\gamma(P)$. The more general choice, adopted in the framework of case-intensional semantics, is to treat predication as intensional in each case. That is, the extension of a predicate P

¹¹Technically it turns out not to matter whether there is a single domain containing extensions at all cases, or there are different domains D_γ at different cases, as long as their cardinality is the same.

¹²This does not limit expressivity, since necessary identity, i.e., identity in all cases, can be expressed as $\Box\alpha = \beta$, using the modal operator “necessarily” (or, idiomatically, “in any case”) that quantifies over all cases; see §3.4.

in a case γ , $ext_\gamma(P)$, sorts not extensions (members of D), but individual intensions (functions from Γ to D) into those to which the predicate applies in the given case and those to which it doesn't. In this way, predication *in a case* can still look further than that particular case: predication is basically intensional. Extensional predicates turn out to be a special case: a predicate P is extensional in case γ if and only if, if $P\alpha$ and $\alpha = \beta$ in that case, then also $P\beta$.

Although extensional predication is a special case logically speaking, it is the usual case from a pragmatic point of view: a large number of important predicates are extensional. Our chief use of non-extensional predicates is in connection with sorts of things (see §3.8 below).

3.4 Modality

In case-intensional semantics, it is rather straightforward to implement modal operators for possibility and necessity. Instead of the usual slogan of modal logic, “necessity is truth in all (accessible) possible worlds”, which triggers a metaphysics of possible worlds as wholly separate but mutually accessible entities, of which we should be suspicious, we can use a metaphysically neutral slogan that is also idiomatic English: something is necessary if it is true in any case. Dually, something is possible if it is true in some (possible) case.¹³

As usually, the modal operators are written as “ \Box ” (“necessarily”) and “ \Diamond ” (“possibly”), and we can treat “ \Diamond ” as an abbreviation for “ $\neg\Box\neg$ ”. The semantics of “ \Box ” is given by universal quantification over cases: $\Box\phi$ is true in a case γ iff ϕ is true in all cases $\gamma' \in \Gamma$. Note that unlike in standard Kripke semantics for modal logic, here no relation of accessibility is needed, and the modal system is therefore simply S5.

Now we have a notion of modality; does this help us to spell out modality *de re*? As argued above, we are looking for modality *de re* in a literal sense: modality of things. So we need to have a good look at the interrelation of singular terms and things in order to understand *de re* modality. We start by looking at so-called “empty” singular terms.

3.5 Singular terms: “empty” terms

It is a well known fact, which has given rise to a lot of semantic effort, that some syntactically well-formed singular terms “misbehave”: they do not single out any-

¹³Hereby we certainly cannot give a reductive analysis of possibility: we have to know that the *cases* are possible before we can employ them here. The same holds true, however, of the more common possible worlds talk—actually, even more so in that mostly, over and above the *possible worlds*, a relation of *relative possibility* (“accessibility”) is invoked.

thing. In our framework, we can already make a distinction at that point: among the so-called “empty” or “non-referring” singular terms, there are some, like “the odd prime”, which do not single out anything in any case; they are, so to speak, completely empty. The most famous example of an “empty” singular term, Russell’s (1905) example of “the present king of France”, is however interestingly different: it does not single out any person now, but it did in earlier times. If cases are temporal (we will come to that below in §4), we can say that “the present king of France” singles out somebody in some (earlier) cases, but not now (in the present case, as it were).

There are several ways to deal with this phenomenon of emptiness, from Russell’s much-discussed move of treating definite descriptions as incomplete symbols to be eliminated in context, to systems of free logic. We go for a simple treatment of these phenomena, along Frege’s lines: we will use a “throwaway” entity $N \in D$ to handle lack of extension in a case. Thus, if $ext_\gamma(\alpha) = N$, this signals that α does not exist in case γ . Accordingly, we can define an (extensional) existence predicate, E : $E\alpha$ holds in case γ iff $ext_\gamma(\alpha) \neq N$.¹⁴

We put “empty” in scare-quotes for a reason. As stated, the term “the present king of France” hasn’t always failed to single out some person—France was a monarchy for quite some time. We normally call a term “empty” because it fails to single out anything *now*, in what we may want to call “the real case”. We already said that from the logical point of view of case-intensional semantics, we are not committed to the existence of a “real case”. Whether there is a “real case”, and thus an extension of a term *simpliciter*, depends on the metaphysics of the specific framework at hand, i.e., on the metaphysical status of the cases in Γ . In standard modal logic, the “actual world” (in the sense of: the world of a context of utterance) can be taken to be the “real case”; in linear tense logic, the present time (the time of the context of utterance) will supply a “real case”. But not all case-intensional frameworks have to be like that.¹⁵ Keeping the semantics symmetrical with respect to the cases is important for a useful, general semantic framework.

¹⁴More properly, relating to what was said about the extension and intension of predicates above, we say that the extension $ext_\gamma(E)$ of the existence predicate in a case γ consists of all those individual intensions \mathcal{J} (all functions \mathcal{J} from Γ to D) for which $\mathcal{J}(\gamma) \neq N$. It turns out, as it should, that if we have $E\alpha$ & $\alpha = \beta$ in a case γ , then we also have $E\beta$ in that case.

¹⁵In fact, in an Ockhamist theory such as case-intensional branching time, which is addressed briefly in note 23 below, there is no “real case”, as none of the possible futures of an utterance context is singled out above all others. Bressan (1972) also motivates his general framework by examples from theoretical physics in which one cannot distinguish a “real case”.

3.6 Singular terms: reference

What does a singular term refer to? Above (§2) we commented on our everyday assumption about using singular terms: the *referent* of a singular term such as “this cat” is a *thing*—that which has a history, and which has properties, including *de re* modal properties. How does this connect with the case-intensional semantic framework?

The standard way to specify a semantics for singular terms, even in intensional logics, is firmly rooted in classical predicate logic. Given a world, a time, or another suitable set of parameters of truth (a case, as we would say), a domain of objects is singled out, and the referent of a singular term is taken to be one of the objects in that domain. There is much discussion about the domains (e.g., whether they are constant across different cases), but the basic assumption is that a domain is a domain of things. In our terminology, this would mean that the extensional domain D is viewed as a domain of things, and that the extension of a singular term in a case is one of the things from the domain. Together with the common assumption about the referent of singular terms, this would mean that the referent of a term in a case (the thing referred to in that case) is its extension in that case—and in fact, it is common to use “referent” synonymously with “extension”.

We hold that the tradition of predicate logic is pushing in an unhelpful direction here. Recall that predicate logic was invented initially to deal with difficulties in the foundations of mathematics: a science of timeless, immutable objects like sets and numbers—no questions of *de re* modality, no questions of persistence. It is clear that the logical framework of predicate logic has to be extended to account for these more worldly phenomena. Should we hold on to the assumption of a domain of things? It is the common thing to do, for systems of quantified modal logic as well as for systems of temporal logic. In case-intensional logic, however, it will not do: extensions can’t be things, and our domain D cannot be a domain of things.

It is perhaps best to establish this for the case of *de re* modality, where the cases $\gamma \in \Gamma$ are possible cases in some adequate sense of possibility (no ontology of “possible worlds” has to be presupposed). This way, we will have an independent background for transferring our semantic insights to the temporal case that is the main objective of this paper. Our consideration is similar to Kripke’s famous Humphrey objection to Lewis (Kripke, 1980, 45n13), but with a twist that should make it less debatable. Consider a thing that is red, but that could be green. Fairly idiomatically we can rephrase this as follows: the thing is red in the case at hand, but it could be green in another case. In case-intensional semantics this means that the extensional predicate “... is red” applies in the case at hand, γ_1 , but not in some other case, γ_2 : $R\alpha$ is true in case γ_1 , but $\diamond\neg R\alpha$ is true there as well (where

R stands for the predicate “... is red” and α is a name of the thing in question). The predicate “... is red” being extensional, this means that the extension of α in γ_1 , $ext_{\gamma_1}(\alpha)$, differs from the extension of α in γ_2 , $ext_{\gamma_2}(\alpha)$, in such a way that “... is red” applies in the one case but not in the other. But this just means that the extension *cannot* be the thing in question. There is, by assumption, just one thing, which is red in one case and green in another. This thing can’t be identical to an extension in a case, since the extensions in the cases γ_1 and γ_2 have to be different in order for an extensional predicate, like “... is red”, to apply to one and not to the other.

This consideration was based on extensional predication. Intensional predication gives an additional argument. In our framework, an extension is something confined to a single case (something that can exist at such a case). If we allow for intensional predication, then in a sentence such as $P\alpha$, the singular term α must refer to the thing, not the extension in a case—otherwise, the intension of P and the referent of α wouldn’t be enough to give a compositional account of the truth or falsity of $P\alpha$ in a case at hand. The upshot is that an individual term α should be taken to *refer to the individual intension* $int(\alpha)$, not the extension $ext_{\gamma}(\alpha)$ at a given case γ .

We can strengthen this verdict by looking at singular terms in more detail. So far, there has been no restriction on the singular terms and their interpretation at all: anything goes, including the empty extension at any number of cases. In our framework, the throwaway entity N is the extension not only for failing definite descriptions like “the present king of France” (in the present case) or “the odd prime” (in all cases), but also for regular terms, like proper names, in cases in which the named object or person simply does not exist. In this respect, “the present king of France” isn’t very much different from “Socrates”: both specify an individual intension, and for both, the extension is empty in the present case, but nonempty in earlier cases.¹⁶ “Socrates” isn’t an empty name—it refers; it is just that at present, its extension is empty. Note that even “the odd prime” has an associated individual intension; it is however empty in all cases, represented as the constant function that assigns the throwaway extension N to all cases. Here we may say that it is a merely technical fact that that singular term refers, whereas in fact we have failure of reference: the fact that there is a referent, is “implementation dependent” as it were, depending on our choice to represent failure of a definite description in a case via assigning the “empty extension”, which in turn is represented by an element N of the domain D .

¹⁶There *is* one relevant difference: “Socrates” refers to a human being, something falling under a sortal concept: a proper thing. “Socrates” is, in the terminology of Geach (1980), a *name for* a man. “The present king of France”, on the other hand, picks out different human beings at different times; its individual intension therefore doesn’t fall under any natural sort. See the discussion in §3.8 below.

For another example of the (potential) “anything goes” of our framework, take the singular term “Peter’s favourite object”. This may have been a soft toy when he was two, a bike later on, then something he got from his girlfriend, or his phone. No matter: the intension of that term is simply some individual intension, a function from Γ to D . (Quite plausibly we should take the extension of that term to be N in all those cases γ in which Peter himself doesn’t exist, i.e., in which $ext_\gamma(\text{Peter}) = N$.) Of course, the resources of natural language for specifying individual intensions are limited, but in principle, *any* function from Γ to D could be the intension of some term, and thus could be referred to. Any individual intension can be an *object of reference*.

3.7 Quantifiers

We have argued that singular terms refer to individual intensions, while their extensions are case-specific. Variables being singular terms as well, this has consequences for the interpretation of quantification: the quantifiers in our framework range over all possible individual intensions. Thus, in a technical development of first-order case-intensional semantics, we will need an assignment for the variables that specifies one individual intension per variable, and the quantifiers will change that assignment as usual, replacing the appropriate individual intension by another.¹⁷

Can we read these quantifiers in the usual way then, as “for at least one thing x ” ($\exists x$) and “for all things x ” ($\forall x$)? This seems doubtful. Consider Peter’s favourite object again. Even leaving to the side the cases in which there is no extension for that term, that “object” behaves strangely. It does not make sense to inquire into “its” persistence, even though the “object” surely has different properties at different times (for example, “it” is big and fluffy in an earlier case, but small and hard now). It makes no good sense either to ask about its *de re* modal properties, even though “it” could be red, or yellow, or green. The term “Peter’s favourite object” certainly specifies an *object of reference*, like any singular term. “Peter’s favourite object” however doesn’t specify a *proper thing*.

It is proper things, though, that we normally care about, and whose *de re* modality and persistence we are trying to understand. This comes out nicely in a double reading of the quantifiers, which does *not* coincide with the purported difference of “possibilist” vs. “actualist” quantification that is much discussed in quantified modal logic. What about the sentence

There is something that is Peter’s favourite object,

¹⁷This meshes well with the fact that all open formulae create a potentially intensional context: even the atomic open formula Fx , for F an intensional predicate, is intensional.

uttered in a case γ ? Taking π to abbreviate the singular term “Peter’s favourite object”, the sentence seems to have the form “ $\exists x x = \pi$ ”, which is trivially true according to our semantics for the quantifiers (we can just assign to x the intension of π). There is however a more interesting reading, which stresses the “thing” in “something”: in case γ , there is a *proper thing* that is (in that case) identical with Peter’s favourite object,

$$\exists x (PTx \ \& \ x = \pi).$$

Here we use “*PT*” to stand for the (intensional) predicate of objects of reference, “being a proper thing”, to be elucidated in §3.8 below.

The distinction between objects of reference and proper things is made even more explicit when one tries to force a *de re* reading for “Peter’s favourite object”. The natural interpretation for a sentence expressing a *de re* possibility, such as

Of Peter’s favourite object it is true that it could be green,

is that there is a *proper thing* (e.g., one of his model trains), which in fact (in the case at hand) is Peter’s favourite object, and of which the *de re* modal attribution is true. The fact that Peter’s favourite object could be something else which in fact is green (i.e., that there is a case in which the extension of “Peter’s favourite object” satisfies the extensional predicate “... is green”), does not seem enough to make the displayed *de re* sentence true. In the same vein, it does make sense to inquire into the persistence of the proper thing that is actually (in a given case) Peter’s favourite object, but not to ask how Peter’s favourite thing, considered as an object of reference, persists.

It is at this semantic level that questions of indeterminism (in the form of *de re* modality) and persistence come together.

3.8 Characterizing proper things

So far, the individual intension $int(\alpha)$ of a singular term α is our technical representation of an *object of reference*. Any function from Γ to D can constitute such an object of reference. In line with our interest in *de re* modality and persistence, however, we are mostly interested in *proper things*, such as cats, pine trees, tables or cups.¹⁸ It is their persistence that a theory of persistence should explain, and their *de re* modal properties that a theory of *de re* modality should illuminate. It

¹⁸It is well known that artefacts such as tables or cups pose specific challenges for the notion of persistence, as illustrated, for example, by Hobbes’s famous example of Theseus’s ship (see Wiggins, 2001, 93f.). At the level of abstraction of the present paper, we will not be concerned with the specific question of artefact persistence, but just presuppose that the semantics gives us a way of singling out proper things as belonging to sorts. This semantic mechanism may well be context-dependent.

would be asking too much, or indeed the wrong thing, if we were aiming at a fully general theory of modality and persistence for *objects of reference*. When asked about the persistence of a thing whose extension in different cases picks out Julius Caesar, the moon, a piece of chalk and a frog (and maybe that *is* Peter’s favourite object), we should simply deny that such a “thing”, even if we can refer to it, persists in any meaningful way, or that we understand what is meant when we hear that *it* could be green.

It should be clear now that this development of objects of reference as individual intensions is different from the standard way of analytic metaphysics, which would probably construe a general notion of an object as a mereological sum of temporal parts of ordinary things, if these are acknowledged, or just as (the contents of) a region of space-time. No temporal parts are invoked in our development. Apart from a leaner ontology, this also means that we can leave the original notion of a part intact, so that for proper things, “part” just means “spatial part”.

How can we distinguish mere objects of reference from proper things? In our framework, we take a lead from the idea that a proper thing falls under a sortal: we characterize proper things semantically by way of characterizing sortal predicates. This idea certainly has a (neo-)Aristotelian ring to it, but we endorse the thought that “a view is not necessarily wrong because Aristotle held it” (Prior, 1967a, 10).¹⁹

It is difficult to determine what the proper sortal predicates are. At the level of abstraction of this paper, we can leave that open (see note 18). We will simply assume that there is an (intensional) predicate of predicates, *Sortal*, such that F is a sortal predicate iff $Sortal(F)$ is true.²⁰ Some useful assumptions about *Sortal* are the following:

- If $Sortal(F)$ and α is a singular term, then if there is a case in which α exists and falls under F (i.e., if it is true that $\diamond(E\alpha \ \& \ F\alpha)$), then α falls under F in all cases in which it exists ($\square(E\alpha \ \rightarrow \ F\alpha)$). Once a cat, always a cat. Bressan calls this “quasi-modal constancy”; the “quasi” comes in because nonexistence at some cases is allowed for. This principle encodes our commonsensical idea that transsubstantiation doesn’t occur: if we have correctly specified the sortal under which something falls, then that sortal will stick, as it were, for life.²¹

¹⁹We are of course not after any specific thesis that the historical Aristotle held. It is a fact, however, that the label “Aristotelianism”, or “neo-Aristotelianism”, for a view of things as belonging to sorts has wide currency.

²⁰Case-intensional semantics easily provides the necessary higher-order machinery. For details, see Bressan (1972) or, more compactly, Belnap (2006) and Belnap and Müller (2012).

²¹In this specific sense we may say that transsubstantiation, which has been a matter of life and death in the history of Christianity, is indeed, but luckily more theoretically, a matter of life and death.

- If $Sortal(F)$ and α and β are singular terms, then if there is a case in which α and β exist, both fall under F , and they coincide in that case ($\diamond(E\alpha \ \& \ F\alpha \ \& \ F\beta \ \& \ \alpha = \beta)$), then α and β are identical in all cases, i.e., they fully coincide ($\square(\alpha = \beta)$). There is thus *no overlap between things of the same sort*. No two cats in the same place. Note that this leaves it open that there might be overlap in the sense that, for example, there is both a statue and a lump of clay constituting the statue at the same place, even though they are not identical: two different proper things of different sorts might very well have the same extension in one case.²²

Bressan calls this principle “quasi-modal separation”; together with quasi-modal constancy, we have specified his notion of “quasi-absoluteness”.

We do not take a stance here as to whether *Sortal* is fully characterized via quasi-absoluteness—ultimately this will depend on the set of cases Γ under consideration, and an informal notion of naturalness may have to be invoked in addition. At least it should be clear that our framework has the resources to spell out the logical aspects of the predicate *Sortal* in as much detail as is needed.

A proper thing is, then, an object of reference (an individual intension) that falls under a *sortal*. Thus,

$$PT(\alpha) \Leftrightarrow \exists F (Sortal(F) \ \& \ F\alpha).$$

Let us see how this works out in the case of the cat, Hannibal. (We will discuss the appropriate set of cases Γ in §4 below; here we simply take cases to be times.) *Cat* is a *sortal*; $Sortal(Cat)$ is true in any case. We abbreviate the singular term, “Hannibal”, as “*h*”. To say that Hannibal is a cat, is to apply the intensional predicate *Cat*, which “looks beyond” any particular case. Cats have cat-histories; things that have different histories, even if they momentarily were to look like a cat, aren’t cats. There is pretty widespread consensus about this role of a thing’s history for its belonging to a sort; for two rather different views agreeing on this, see, e.g., the swampman thought experiment by Davidson (1987), and Thompson (2003). Given our present distinction between objects of reference and proper things, we can support this position in the following way. Let the singular term “*c*” have as its referent a proper thing different from Hannibal, say a teacup. There are, therefore, individual intensions $int(c)$ and $int(h)$ that represent the cup and the cat, respectively, and that fully specify their histories. Now define the individual intension \mathfrak{I}

²²We do not wish to take a stance on this issue; here it is enough to point out that the logical framework leaves this open as a metaphysical question, by being able to represent both options. Case-intensional logic is not metaphysics-driven logic, but meant to be a tool for clarifying metaphysical questions by providing adequate formal representations of differing views.

as follows:

$$\mathfrak{I}(\gamma) = \begin{cases} (int(h))(\gamma) & \text{for } \gamma = t_0, \\ (int(c))(\gamma) & \text{for } \gamma \neq t_0. \end{cases}$$

Let “Hcup” be a singular term that has the individual intension \mathfrak{I} as its object of reference. (No problem; maybe *that* is Peter’s favourite object.) In case t_0 , i.e., locally to case t_0 , this object of reference has, by assumption, the same extension as “Hannibal” in that case: $ext_{t_0}(h) = (int(h))(t_0) = \mathfrak{I}(t_0) = ext_{t_0}(\text{“Hcup”})$. Accordingly, in case t_0 , “Hcup = h ” is true; it is impossible to distinguish Hcup from Hannibal by focusing on case t_0 alone. It would however be wrong to say that Hcup is a cat: it clearly isn’t; any other case will show this. And even if we change the definition of \mathfrak{I} to

$$\mathfrak{I}(\gamma) = \begin{cases} (int(h))(\gamma) & \text{for } \gamma \geq t_0, \\ (int(c))(\gamma) & \text{for } \gamma < t_0, \end{cases}$$

which may be a more appropriate candidate for Peter’s favourite object, what we get is not a cat, but something like a swamp-cat: something that, even though it may forever be indistinguishable from a cat after t_0 , isn’t a cat since it doesn’t have a cat’s history. In order to see whether some object of reference (an individual intension) is a proper thing of a specific sort, one needs to look further than any given case. Sortal predication, and therefore the notion of a proper thing, is highly intensional.

4 Moments as cases: a case-intensional discussion of persistence

We haven’t been precise so far in specifying what our set of cases Γ should be for a proper discussion of proper things and their indeterminism and persistence. Accordingly, we have left it vague what we take to be the extensions in D . In line with the overall aim of our paper, now is the time to commit.

We hold that ultimately, a realistic environment for the discussion of indeterminism and persistence will have to be based on cases in branching time or, more adequately, in branching space-time. These frameworks pose technical challenges that we need not discuss here.²³ It will be sufficient to give a temporal reading to Γ and to discuss the question of persistence independently of the question of *de*

²³See Belnap and Müller (2012) for details. The branching time framework, based on ideas by Kripke (see Ploug and Øhrstrøm, 2011), Prior (1967b), and Thomason (1970), is described in detail in Belnap et al. (2001). It is important, in combining time and modality, to allow for incompatible cases at the same (clock-)time, so the cases shouldn’t be called “times”, but “moments”. Ockhamist semantics for the future tense further complicates matters. For branching space-times, see Belnap (1992) and Müller (2010).

re modality, simply assuming the case-intensional semantic framework that was motivated by these two phenomena together.

Our cases are therefore temporal; we can take them to be moments. Thus, a term will have an extension at any given moment; the “throwaway” extension N will represent the fact that the term in question has no extension at a given moment. An individual intension will accordingly be a function from moments to extensions. Again, things, the referents of singular terms, which have a history, are properly represented by the intensions, not the extensions: the referent of a singular term, an object of reference, is an individual intension, a function from moments to extensions.

What are these extensions? This question is of course important for our semantics, but also for its interpretation vis-à-vis the persistence debate. In a given case (at a given time), the extension of a term will have to be something that “fits” into the case; it cannot as it were extend beyond that case (see §3.6 above). Given the fact that cases are momentary points of time, an extension therefore has to be something that is not temporally extended. This makes it plausible to take the extensions to be either stages, or states, of things. We go for the former. Note that, as laid out above, the extensions, i.e., the stages, are *not* themselves things. Our semantic choice for stages as extensions does not commit us to the existence of Stages as proper things. It *may be* (in the neutral sense of: “the framework does not exclude”—see note 22) that there are Stages: proper things that only exist in a single case, so that we may, in some weak and potentially confusing sense, identify them with their one non-trivial extension. We take this to be a broadly empirical question, which we refrain from addressing here.

Now let us move closer to the question of persistence: we want to model the true fact that Hannibal once was a kitten, but isn’t any longer. In order to keep things simple, we will not speak about a cat being a kitten or not in a given case (*kitten* is a phased sortal predicate, which has intensional semantics again); rather, we will use the extensional predicate of *weighing more than 1kg*, K . In order to model the fact that Hannibal the cat once was a kitten, weighing less than or equal to 1kg ($\neg K(h)$ in case m_1), and now weighs more than 1kg ($K(h)$ in case m_2), we have to have, minimally, the two cases m_1 and m_2 ($\Gamma = \{m_1, m_2\}$) and two extensions $c_1 \neq N$ and $c_2 \neq N$, cat-stages if you wish (so, including the throw-away, $D = \{N, c_1, c_2\}$). The individual intension that h refers to, \mathfrak{J} , is the function mapping m_1 to c_1 and m_2 to c_2 . This individual intension we take to fall under the extension of the sortal predicate *Cat* at all cases (remember quasi-modal constancy, §3.8).

Being of a real sort (being a cat), Hannibal persists, and so it makes sense to ask how his persistence is reflected in our framework. It turns out that our framework is sufficiently neutral to allow an interpretation in terms of either endurance,

perdurance, or exdurance. We look at the three contenders in turn.

Endurantism. Hannibal exists at each of the two cases in question: h has a non-empty extension there ($\mathfrak{J}(m_1) \neq N$; $\mathfrak{J}(m_2) \neq N$). To say that it is one and the same cat that weighs less than 1kg in one case (at m_1) and not in another case (at m_2), is to say that the *referent* of the singular term h is *the same individual intension* \mathfrak{J} (the same function from cases to extensions), independently of the case. The difference in the application of the (extensional) predicate K is due to the *different extensions* at the two cases. Hannibal is, if you wish, “wholly present” in both cases: he has a non-empty extension at both m_1 and at m_2 , and none of his parts is missing in any case. The extensions are three-dimensional stages, but crucially, they are *not* cats, nor any other proper things, nor are they temporal parts of a cat: cats have tails, paws etc. as their spatial parts, but no temporal parts.

This appears to be a simple, coherent account of what is going on, without any need for revision.

Perdurantism. For the perdurantist, there is no important distinction between extension and referent. The extension of the term h is a space-time worm; in our simple model, this amounts to taking the extension of h to be the graph of the function \mathfrak{J} , represented, for example, by the set that has as elements the pairs $\langle m_1, c_1 \rangle$ and $\langle m_2, c_2 \rangle$. To say that Hannibal weighed less than 1kg in case m_1 is to say, on that view, that there is a *temporal part* of the space-time worm (of the graph), which is a thing itself, that weighs less than 1kg; in our example, this will be the stage at m_1, c_1 . Another temporal part of the worm, c_2 , is heavier. This is extensional predication. Intensional predication can be accounted for as well: it can be read as predication of the whole worm.

From the point of view of case-intensional semantics, this reading is similar to endurantism—what a singular term *refers* to is rather similar in both cases (the function vs. its graph). Endurantism, as the home theory of case-intensional semantics, however also speaks about *extensions at cases*: the values of the intension-function, which are extensional entities that are themselves *not* things. Perdurantism, in comparison, trades a merely semantic phenomenon—the difference between the extension of a term in a case and its intensional reference—for a metaphysical theory of temporal parts of things, which themselves have to be yet more things. This appears to be unnecessarily revisionistic. Once the semantics is clarified, there is no need for the ontological move implied by perdurantism any more.

Exdurantism. Exdurantism, as proposed by Sider (1996, 2001), collapses extensions and referents in the other direction: according to that view, the term h refers

to its endurantist extension in a given case, which is a stage. All predication therefore has to be extensional—there simply is nothing over and above the extensions to predicate anything of. A temporal counterpart relation is needed in order to bind together the various extensions to form something like a persisting thing.

This view nicely captures the extensional aspects of our endurantist theory, but it falls short of the intensional aspects. These all need to be simulated by means of a counterpart relation. Therefore, exdurantism is also highly revisionistic, taking us to be referring to momentarily existing, instantaneously vanishing entities when we think we are referring to, e.g., a cat as something that has a history.

There is no need to go along with this type of revisionism once we see that the semantic basis that allows a complicated reading in terms of exdurantism, also allows for a perfectly simple reading in terms of endurantism.

5 Conclusion

We have used the phenomena of indeterminism, in the sense of *de re* modality, and persistence, to motivate the semantical framework of case-intensional semantics, which allows a detailed characterization of the proper things to which indeterminism and persistence are attributable. The temporal reading of that semantical framework, laid out in §4, allows for the representation of all three major positions in the persistence debate: endurantism, perdurantism, and exdurantism. We claim that this supports the view that endurantism, our commonsensical theory of persistence, wins the day: there is no need for revision, as any purported advantages of the revisionistic positions of perdurantism and exdurantism come to nothing, given the semantical equivalence that we have shown.

Commonsensical endurantist persistence ain't broke. There is no need to fix it.

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