What would it take to tame the verbal Hydra?

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Abstract

Like the mythological Hydra, prominent theories of the verb phrase boast multiple heads, either in parallel as "flavors" of the v head (Folli and Harley, 2005), or in a selectional series (Ramchand, 2008). In either case, the need for compatibility between particular verbal heads and particular lexical roots requires that a considerable amount of information be duplicated between the lexicon and the syntax. We posit the viability of a single unified verbal head which drives root selection via ordinary type-sensitive composition, diminishing the amount and kinds of information that have to be duplicated. To construct the meaning of this unified verbal head, we leverage two recent ontological innovations in the theory of event structure: the use of degree arguments to represent change (e.g. Hay et al., 1999; Kennedy and McNally, 1999; Kennedy and Levin, 2008; Kennedy, 2012) and the use of force functions to represent inputs of energy (forces) (Copley and Harley, 2015). We find that the denotation of the unified verbal head then requires only a few minor adjustments to current understandings of compositional theory and the division of labor at the syntax-semantics interface. We conclude that the verbal Hydra can be tamed, at least to the extent that these adjustments are plausible.

Keywords: verb phrase, ontology, event structure, cumulativity, degree arguments, force arguments

1 Introduction

Verb phrases offer a rich proliferation of phenomena which have both semantic and syntactic reflexes. Some of these are exemplified in (1):

(1) a. telic vs. atelic vs. variable telicity
climb the mountain vs. *dance* vs. *eat apples/the apple*
b. different causal paraphrases
CAUSE vs. BECOME vs. DO vs. ...
c. intuitive causation vs. no intuitive causation
heat the soup vs. *go to the store*

d. intuitive degree scale vs. no intuitive degree scale
   heat the soup, eat the apple, go to the store vs. *dance the polka*
e. delimiting/homomorphic object vs. non-delimiting/non-homomorphic object
   eat the apple, mow the lawn vs. *heat the soup, push the cart*
f. change vs. no change
   put vs. *stay*

This list includes only some of the major factors that arise in English; other issues, including those having to do with the onset of the event, arise in other languages (see, e.g. Marín and McNally, 2011; Choi, 2015; Ritter, 2018).

These facts bear on where and how one draws the line of the interface between syntax and semantics. A broad contrast can be drawn between accounts that privilege putting more information into lexical entries (Levin and Rappaport Hovav, 1995) and those that privilege structural reflexes of these phenomena (Borer, 2005a). A hybrid method is to use multiple "light" verbal heads, either in parallel (i.e., in complementary distribution; Folli and Harley (2005)), or in series (i.e., in an extended projection; Ramchand (2008)). In these approaches, with which we are sympathetic, different classes of verbs use different heads with unique semantic content and related structural properties, yielding a division of labor which is neither purely lexical nor purely structural.

While all such theories above pay close attention to the syntax-semantics interface, there is still room for improvement. For one, theories with multiple heads need to duplicate a certain amount of information across the lexicon and the syntax to ensure that the right syntactic heads are associated with the right roots. We could also wish that the proliferation of null verbal heads could be constrained in a principled way.

With this wishlist in mind, we ask: What would it take to reduce the many-headed Hydra[1] of the verb phrase down to a single v head? Our answer begins with a shift in the ontology, which "explodes" the Davidsonian event argument.

Davidsonian event arguments (Davidson, 1967) have been widely adopted in formal approaches to the semantics of the verb phrase. Copley and Harley (2015) proposed that while Davidson was right about there being such implicit arguments, he was wrong in thinking that they correspond to the commonsense idea of an event. Rather, the Davidsonian argument of a dynamic[2] verbal predicate corresponds more closely to the commonsense idea of a *force*—an input of energy. One motivation for this move is that although the commonsense

[1] In Greek mythology, the Hydra of Lerna was a ferocious, many-headed serpent that was eventually killed by Heracles and his nephew Iolaus. According to Wikipedia, ancient sources disagreed as to the number of heads the Hydra had. We feel this fact makes the Hydra unusually appropriate as a metaphor for the verb phrase. We must be careful with this metaphor, however, since apparently for every head that was cut off, two (or was it three?) grew in its place, an outcome that we wish to avoid.

[2] We use the word *dynamic* in the sense of 'energetic', though it is also often used in the sense of 'involving change'; see Copley (2019) for discussion. For us, dynamic predicates make reference to an input of energy which arises from a situation, and stative predicates make reference to situations. We will have nothing to say about stative v here.

idea of an event is a change of some kind (Cleland, 1991), not all Davidsonian dynamic arguments require change. Notably, the Davidsonian argument of verbs of maintaining such as *keep* and *stay* is both dynamic and changeless. Moreover, this approach aligns the treatment of atelic dynamic predicates (activities and semelfactives) with that of telic predicates.[3]

If this move is correct (*pace* Maienborn (2005)), then change is irrelevant to the individuation of Davidsonian arguments. However, change is clearly implicated in a host of predicate types. Change of various kinds has been well represented by the use of differences between two degrees on degree scales (Hay et al., 1999; Kennedy and McNally, 1999; Kennedy and Levin, 2008, a.o.). Still, if degrees are used to represent change, we think it's overkill for the Davidsonian argument to also represent change. Thus we propose a division of labor: energy is reified by force arguments and change is reified by degree arguments.

With this division of labor, we find that the Hydra can plausibly be rendered monocephalic. This is in large part because the advantages of both forces and degrees are retained, allowing a natural force-theoretic account for verbs of maintaining and activities while also yielding an intuitive degree-based account of the classical homomorphisms (Tenny, 1987, 1994; Verkuyl, 1993; Krifka, 1989, 1992, 1998). We hypothesize that English dynamic verbs make reference to a conceptual structure in which an input of energy causes a (possibly zero) difference in the degree to which a predicate holds in a resulting situation. This meaning, which in its event-theoretic version is familiar (Koenig and Chief, 2007; Kennedy and Levin, 2008; Beavers, 2012, a.o.), is contributed by the verbalizer.

On the lumping-splitting continuum, our aim here is obviously to lump. It's true that we are not delving deeply into the diversity of verbal roots even in English, since our goal is instead to arrive at a compositional semantics that distills what is common to English dynamic verbal predicates. But along the way, we note where broad differences between lexical roots play a key role, which should be informative for closer investigation of particular verbal roots ("A verb is a world," Louise McNally, p.c.).

For example, in the case of telicity, we argue that the various telicity properties of particular roots arise from the different temporal relationships possible between cause and effect. This is consistent with the idea (see, a.o., Filip, 2008) that telicity is not represented in the logical form in English. We argue that insofar as root meanings provide a quantization feature of scales, they thereby specify either *launching* causation (the cause precedes the result, the predicate is telic), *entrainment* causation (the cause and result happen at the same time, the predicate is atelic), or both launching and entrainment causation (the predicate has variable telicity). In this way, temporality plays a role at the conceptual level, even though it is not represented in the compositional semantics.

To take another example of variation that we attribute to root meanings: Variation in the role of the object (i.e., homomorphic/non-homomorphic) in-

[3]The approach to telicity and eventiveness outlined in Beavers (2008) also attempts to characterize dynamicity and (a)telicity in a unified framework; however, this proposal misses the dynamic verbs of maintaining as well, due to the claim that 'movement' is the core property of dynamic predicates.

volves differences in whether the object is in a position to provide the scale (and see Ramchand, 2008). The reason, then, that homomorphisms show up in some, but not all, verbal predicate meanings is because the extent dimension can only be invoked with the object in the correct position (for scalar treatments of quantization see, a.o., Kennedy, 2012; Kardos, 2019a).

In addition, we attribute the difference between manner and result verbs to different ways in which roots compose with v: change-of-state verbs lexicalize a measure function, while manner verbs lexicalize a property of the force. And the fact that verbs of maintaining have dynamism but lack change will be encoded directly in the meaning of the root (contra Copley and Harley (2015)).

We also hope to be able to limit the syntax-semantics interface—i.e., the information that is shared between the lexicon and the compositional system—to as small a number of elements as possible beyond the evaluation function, compositional rules, and type theory. In short, the less machinery we can get away with adding to the grammar, the better. In this quest, a dual ontology—along the lines of Barwise and Perry's (1983) "real" vs. "abstract" distinction and following Copley and Harley (2015)—does important work for us, and potentially opens up some space for cross-linguistic distinctions in the realization of the "same" root (as in, e.g. McNally and Spalek, 2019; Beavers and Koontz-Garboden, 2020).

We now lay out the ontological shifts we use. First we present background on entrainment (effect during cause) and launching (effect after cause), and we show how we model entrainment with inputs of energy (conceptual forces). We represent conceptual forces on the linguistic level as functions, as in Copley and Harley (2015). We then add degrees to the picture, arguing that Kennedy and Levin's (2008) view of atelicity actually begins to resemble entrainment, giving us a good starting place from which to construct the meaning of the unified v head. We present our proposal of what degree scales are, how they interact with roots, and the unified denotation of the hypothesized verbalizing head v.

In the sections after, we give the adjustments to theory needed to account for the usual predicate classes: changes-of-state (section 3), incremental theme predicates (section 4), activities and semelfactives (section 5), verbs of maintaining (section 6), and ditransitive predicates (section 7).

2 Background and formal details

2.1 Telicity is launching and atelicity is entrainment

It has long been noted in both psychology (Michotte, 1946) and the cognitive linguistic tradition (e.g. Shibatani, 1973; Talmy, 1976; Croft, 1991), that causes can have either of two temporal relationships to their effects. We use Michotte's terms, translated from French, for the two relationships, given in (2):

(2) a. Launching: effect after cause
b. Entrainment: effect during cause

To illustrate these two relationships, think of pushing a cup along a table. If you *push a cup to the edge of the table* (a telic predicate), the result that is described is the cup's being at the edge of the table, which happens as you finish applying the energy to the cup. However, if you *push the cup along the table* (an atelic predicate), the result that is described is the cup's moving along the length of the table; this result obtains as soon as you impart the pushing force to the cup. That is, there a result that happens at the same time as the causing input of energy. So results are not constrained to occur after their cause—and moreover, results need not be states.

Entrainment, however, poses a serious problem for Davidsonian events as typically understood. There are two reasons why activities were not generally treated as having causation and a cotemporal, entrained result in such frameworks. One reason is empirical: Activities (prototypically atelic predicates) fail tests that are supposed to distinguish result events from causing events, such as the test for restituitive *again* (see, e.g., Beck and Johnson, 2004, and refs therein).

(3) a. #Mary danced, and later John danced again.
b. #Sheila sang, and later Bruce sang again.

The idea that atelic dynamic predicates are simplex events is taken to explain why there are not two scopes for *again* with such predicates. These two issues, event individuation and the scope of *again*, have meant that entrainment was considered a non-starter for result event arguments.

But although availability of two readings for *again* is widely held to diagnose the presence of two Davidsonian arguments, this conclusion appears to rest on the fact that the two scopes of *again* pick out reasonable subevents in some cases of telicity. But in actual fact, telicity is not a necessary condition on the low scope for *again*. The facts in (4) illustrate this, since the (b) examples are atelic and yet have a low reading (as well as the expected repetition (high) reading (Folli and Harley, 2006)):

(4) a. Allan waltzed Matilda around and around.
b. Later in the evening, Bruce waltzed Matilda around and around again.

(5) a. The wind pushed the cup towards the edge of the table.
b. Later, Mary pushed it towards the edge of the table again.

(6) a. During the initial quake, John's quick reflexes allowed him to keep the vase on the shelf.
b. During the aftershocks, Mary kept the vase on the shelf again.

Thus, using *again* as a diagnostic for the presence or absence of a cotemporal result is problematic. Copley and Harley (2015) argue that a framework that represents cotemporal results for atelic predicates allows the distribution of *again* to be purely type-driven, composing via Predicate Modification with type *st* nodes; this kind of analysis will work for the present proposal as well.

Another reason that entrainment has not been in fashion in formal semantics is conceptual: It seems to go against a popular notion of Davidsonian events where they are individuated on the basis of their thematic roles (Carlson, 1998). In activities there is one agent participant acting in a single way at a single time and place, and there is nothing that happens after the agent's action, so there is no reason to say there are two events. Hence, the intuition that activities involve entrainment cannot be cashed in as one Davidsonian event causing another.

One way this can be seen is from the fact that work on Davidsonian event semantics has not paid any explicit attention to entraining causation. There is a tremendous amount of work on launching causation, corresponding to a subevent analysis of telicity: Pustejovsky (1995); Dowty (1979); Rothstein (2000); Higginbotham (2000); Ramchand (2008), among others.

(7) Pustejovsky (1995)
Mary ran to the store: [cause(act(m), become(at(m, the-store) BY run]

(8) Higginbotham (2000)
John saddled the horse: $\exists e \exists e'$ [agent(John,e) & saddled(the horse,e') & (e, e') is a telic pair]

(9) Ramchand (2008)
'defuse-the-bomb'(e), where $e = e_1 \rightarrow (e_2 \rightarrow e_3)$: [*initiate-defuse*(e_1) & *process-defuse*(e_2) & *result-of-defusing*($e3$)]

In all of these, there is a causal relation between at least two temporally sequential event-like elements. However, activities such as *sing* or *run* are typically treated as simplex events, not causal at all. The sole exception here is Ramchand (2008), in which some activities, generally unergatives, are treated as involving two verbal heads: an initiator head, encoding causation by a stative subeventuality, and a process head encoding the dynamic process subeventuality. We think Ramchand is absolutely correct about these being causal. Still, note that her causal analysis of unergatives is not an entrainment analysis but rather a launching analysis, since what the initiator initiates is a temporally subsequent process.

While Davidsonian event causation for entrainment was stuck on the launch pad as it were, there was a separate development in formal semantics that more accurately captured the notion of entrainment for certain predicates, even though causation was not the main focus. This development was the rise of degree scales to explain variable telicity in predicates such as *heat the soup*, and its extension to incremental theme verbs (Hay et al. (1999); Kennedy and McNally (1999); Kennedy and Levin (2008); Kennedy (2012), and see also Verkuyl and Zwarts (1992)). The idea behind the degree approach is that the predicate makes reference to a scale, which has a direction, but which may or may not have an endpoint in that direction. Telicity corresponds to the case where satisfaction of the predicate occurs on reaching the maximum endpoint of the scale if it has one ('closed' scale). Atelicity, on the other hand, corresponds to the case in which there is no endpoint in the relevant direction ('open' scale), and the predicate is satisfied by any minimal amount of change that occurs

in the relevant direction. With any given verbal predicate, we thus need to check whether the result begins as soon as the scalar change begins (atelic), or whether the result obtains only at the end of the scalar change (telic), to see which relationship we have. Homomorphisms between the event and quantized or non-quantized objects can be relevant to this checking. For instance, if you eat a bowl of soup, the result of the (quantized) bowl of soup being eaten doesn't occur until you are finished eating. On the other hand, if you eat soup, from the very beginning you achieve the result of (non-quantized) soup being eaten.

As Kennedy and Levin (2008) note, a degree story of this kind for telicity and atelicity can be just a comparative analysis (Hay et al., 1999; Abusch, 1986), eschewing talk of causation in favor of identifying the differences that such verbs evoke along degree scales. However, Kennedy and Levin also point out that a difference value is not sufficient; events also have to be included in the interpretation of the denotation if telicity and atelicity are to be explained.

The way Kennedy and Levin introduce events is very interesting. Note in the quotation below that they introduce the event using what Ramchand 2008 calls "causal glue"—that is, it is introduced via a "result of" relation.[4]

> [W]e propose that the adjectival core of a [degree achievement] is a special kind of derived measure function that measures the degree to which an object changes along a scalar dimension *as the result of* participating in an event. (Kennedy and Levin, 2008, p. 17, italics ours)

Now that the causal relation has been brought in, we can ask whether Kennedy and Levin (2008) represents both launching and entrainment. Indeed, they, like everyone else, duly represent telicity as launching, since the maximum is reached at the end of the event. However, they also give us, on a close read, a way to entail entrainment (the effect occurring during the cause) for an atelically described event.

Consider an atelically described event where you heat the soup more than the minimal standard; that is, the soup undergoes something more than a minimal positive change on the temperature dimension. Intuitively, we know that you are applying the heat at the same time that the soup is heating up. Kennedy and Levin (2008), who cannot really talk about inputs of energy in their event-theoretic framework, do not directly express this intuition, but their framework does suggest it.

To see this, consider Kennedy and Levin's description of their analysis of atelicity below:

> [Degree achievements] can always express relations to minimum standards, the resulting truth conditions make the verb true of an object and an event as long as that object undergoes some change

[4] This causal glue only appears in the interpretation of the denotation of degree achievements, not in the denotation itself; compare this to the "leads to" relation in Ramchand (2008), which is explicitly in the denotations; it is the "→" that appears in (9) above.

> relative to the scalar dimension encoded by the [degree achievement], i.e., as long as its degree of the relevant property is greater at the end of the event than it was at the beginning. This derives the atelic interpretation.

Since the event we are considering (heating the soup) reaches the minimum standard of change by the end of the event, it correctly qualifies as atelic under Kennedy and Levin's analysis. It does so "as a result of its participation in the event". But notice also: Since at the end of the event the change in temperature of the soup exceeds the minimum standard of change, sometime during the event the soup must reach the minimum standard of change. What is this, if not a result that is occurring cotemporally with the event that causes the change?

While the event-theoretic analysis in Kennedy and Levin (2008) thus does allow us in this way to get to entrainment, we think that the intuition of entrainment would better served through an ontology that allows us to directly talk about inputs of energy, and thereby to directly talk about cotemporal results. The specified maximum and unspecified maximum cases would then reflect the two different temporal relationships between cause and result: launching and entrainment respectively. In cases where the maximum on the scale is specified, an input of energy—a force—moves the current degree along a scale, but the result only occurs at the time when the endpoint is reached. Therefore, in these cases, the cause precedes the effect, yielding launching and telicity. However, if a maximum is not specified, and if any amount of difference "counts" for the effect to occur, the effect starts to occur at (more or less) the same instant that the energetic cause starts to occur, yielding entrainment and atelicity.

2.2 Forces and degrees together give us a chance at taming the Hydra

We have just argued that telicity is best understood as launching (effect after cause) and atelicity is best understood as entrainment (effect during cause). We have done this because we think that having an ontology that more closely aligns with that intuition will give us a chance at a kind of unification of dynamic verbal semantics, which will in turn allow us to cut off all but one of the verbal Hydra's heads.

There are two main ways that theories can have multiple heads: in parallel (the "flavors of v" theories, where heads are in complementary distribution Harley (2005); Folli and Harley (2005), Copley and Harley (2015)) or in series (selectional chain theories, Ramchand (e.g. 2008)). These theories treat major classes of verbs as follows in (10) - (14):

(10) Change-of-state

a. Folli and Harley 2005: $[_{vP}\ v_{BECOME}\ [_{SC}\ DP\ Root]]$
b. Copley and Harley 2015: $[_{vP}\ v_{BECOME}\ [_{SC}\ DP]\ Root]]$
c. Ramchand 2008: $[_{ProcP}\ PROC\ [_{ResP}\ DP\ RES\ Root]]$

(11) Incremental theme

a. Folli and Harley 2005: [$_{v}P$ manner [$_{vP}$ [v_{DO} DP]]]
b. Copley and Harley 2015: [$_{v}P$ manner [$_{vP}$ [v_{APPEAR} DP]]]
c. Ramchand 2008: [$_{InitP}$ $INIT$ [$_{ProcP}$ $PROC$ DP]]

(12) Activities

a. Folli and Harley 2005: [$_{vP}$ [v_{DO} N]]
b. Copley and Harley 2015: [$_{vP}$ [v_{DO} N]]
c. Ramchand 2008: [$_{InitP}$ $INIT$ [$_{ProcP}$ $PROC$ DP]], [$_{ProcP}$ $PROC$ DP]

(13) Verbs of maintaining[5]
Copley and Harley (2015): [$_{vP}$ v_{STAY} [$_{SC}$ DP Adj]]

(14) Change-of-location/possession (ditransitive)

a. Harley 2005: [$_{vP}$ v_{CAUSE} [$_{PP}$ DP [P DP]]]
b. Ramchand 2008: [$_{InitP}$ $INIT$ [$_{ProcP}$ DP $PROC$ [$_{Res}$ RES DP]]]

In our quest to simplify the inventory of verbal heads, these classes constitute the explananda. Now, a significant motivator for the postulation of each type of head in this literature is to distinguish telic and atelic classes of verbs, particularly in the split between Cause/Become (telic) on the one hand and Do (atelic) on the other (*pace* Folli and Harley (2006)). However, in our discussion above, we noted that atelically described events can be conceptualized as causal if we consider them to be cases of entrainment. If we can allow a result to happen cotemporally with its cause, as force-talk allows us to do, nothing about causation entails telicity.

So, a force-theoretic approach to causation can in principle resolve the Cause/Become vs. Do split. But if this is the case, why weren't Copley and Harley (2015) able to unify Cause/Become vs. Do? They couldn't, because they lacked a reification of change. The focus of Copley and Harley (2015) was to reify energy (as force functions) rather than changes (as events). As it happens, however, this meant they had to hard-code each change as the complement of a distinct v; they had no general way of representing a change, so each variety had a different formal type.

We can ask a related question about Ramchand's theory. In her framework, there is no Cause/Become/ Do proliferation, and agentive activity predicates are indeed represented as causal. Why couldn't this theory then tame the Hydra? The answer is that, given the notion of a Davidsonian (sub)eventuality, Ramchand had no access to the notion of entrainment. Thus, she has to separately individuate the process and result subeventualities, since the concept of a cotemporaneous result, or a result that is itself a process, cannot be represented.

To tame the Hydra, then, what we need is to reify *both* energy and change. We will use degree arguments to represent change, as in the degree literature.

[5]Note that verbs of maintaining would not pose any special syntactic issue for either Folli and Harley (2005) or Ramchand (2008); they do, however, pose a semantic issue as discussed above and following Copley and Harley (2015), due to the difficulty of representing entrainment with the usual understanding of Davidsonian event arguments.

We will not need event arguments at all; in fact, there is nothing left for them to represent. Using force functions to represent energy and degree arguments to represent change, we will at last be able to extend the causal analysis to all of the above verb classes. The hypothesized unified meaning of the verbal head is that an input of energy impels a (perhaps zero) change in a degree on a scale (see, e.g., Koenig and Chief (2007) and Kennedy and Levin (2008) for event-theoretic antecedents to this proposal).

Do we really need to reconceptualize events as involving *both* energy reified as forces and change reified as degrees? Should we not perhaps make doubly sure whether degrees, in combination with a conventional event-theoretic semantics, could not do the job? After all, between them, Kennedy and Levin (2008) and Kennedy (2012) provide a coherent picture of degree achievements (change-of-state) and incremental theme classes respectively. On the semantic side, they would certainly be able to account for the meaning of change-of-location/possession. Can such an account also represent activities and verbs of maintaining as entrainment? If your answer to this question is yes, then your interpretation of their event arguments is that they *do* represent inputs of energy, contrary to usual assumptions. This is a possible position; it is possible to believe that Davidsonian arguments represent inputs of energy, without also believing (as in Copley and Harley (2015)) that such inputs of energy need to be treated formally as functions. For arguments that inputs of energy do need to be represented formally using functions, rather than with an event entity, see Copley and Harley (2015), Copley (2022), and section 2.3 below.)

We also contend that the picture of the syntax-semantics interface in Kennedy and Levin (2008) and Kennedy (2012) is problematic. To see this, let's take a closer look at how Kennedy and Levin (2008) glue the event to the adjectival semantics for degree achievements. They build the verb meaning from difference functions. These are derived measure functions (following Kennedy and McNally (2005)) that represent a difference between a degree and the comparative standard, as in (15):

(15) Difference functions (Kennedy and Levin, 2008, ex. (23))
For any measure function $\mathbf{m}$ from objects and times to degrees on a scale S, and for any $d \in S$, $\mathbf{m}^{\uparrow}_{d}$ is a function just like $\mathbf{m}$ except that:
a. its range is $\{d' \in S \mid d \preceq d'\}$, and
b. for any x, t in the domain of $\mathbf{m}$, if $\mathbf{m}(x)(t) \preceq d$ then $\mathbf{m}^{\uparrow}_{d} = d$

Then they apply the "causal glue" via what they call the *measure of change* to get what is described in the quotation above, as shown in (16):

(16) Measure of change (Kennedy and Levin, 2008)
For any measure function $\mathbf{m}$, $\mathbf{m}_{\Delta} = \lambda x \lambda e \,.\, \mathbf{m}^{\uparrow}_{m(x)(init(e))(x)(fin(e))}$

Finally, they add a **pos**(itive) operator, appropriately including an event as in (17) (following Piñón, 2005), which makes the whole verbal predicate type *et* (given that the comparative argument has already been saturated). Thus we

arrive at their core meaning of degree achievements, given in (18).

(17) **pos**$_v$ operator (Kennedy and Levin, 2008, ex. (26); we will not use)
pos$_v = \lambda g \in D_{m_\Delta} \lambda x \lambda e \,.\, g(x)(e) \preceq \mathbf{stnd}(g)$

(18) Core meaning of degree achievements according to Kennedy and Levin (2008, ex. (27))
pos$_v(\mathbf{m}_\Delta) = \lambda x \lambda e \,.\, (\mathbf{m}_\Delta)(x)(e) \preceq \mathbf{stnd}(m_\Delta)$

This analysis accounts for the facts that Kennedy and Levin want to account for, namely telicity judgments in degree achievements. However, from the syntax-semantics point of view, their analysis has two properties that run counter to consensus on the division of labor in the verb phrase.

The first problem is that they need two forms of every adjective: one that has no change, for regular stand-alone adjectival predication, and one that includes change, for the verbal deadjectival structure. This is problematic to the extent that the same form is apparently contributing a different meaning in two different structures. It's not a fatal problem, and could potentially be resolved compositionally in a similar vein to our proposal here, but as it stands, it's not ideal from a syntax-semantics interface perspective.[6]

The second, more serious problem is that causal glue *is* the main show in dynamic verbal semantics. It should not be encapsulated within the adjectival root. We know this because the morphosyntax of deadjectival verbs cross-linguistically wear the division of labor between the verbalizer and the adjectival root on their sleeves: to make a deadjectival causative verb, you add a morpheme that's recognized as adding causation. Causation is not in the adjective, it's in the verbalizer.

A possible response could be to say, "Ah, but the measure of change *is* the v head" (and see Kennedy and Levin (2002); Caudal and Nicolas (2005), Stensrud (2009), and Piñón (2008)). To which we say: Great! This is more or less what we will propose. But we can't use the measure of change proposed by Kennedy and Levin (2008), as it inappropriately references the theme of the adjective, and it scopes under a *pos* operator, neither of which a v head would do.

We need, then, to differentiate between a verbalizing causative element and the rest of the components of dynamic verbs. We have already argued that we need to represent causation in such a way as to capture the launching/entrainment distinction. We now turn to a framework which addresses both of these desiderata by reifying energy in v, with force functions, and change in the complement of v, with degree arguments.

[6] A reviewer suggests a friendly amendment to Kennedy and Levin's system that capitalizes on the idea that degree achievements could be modelled as (always) including comparative morphology, as proposed in Bobaljik (2012) See fn. 22for a discussion of our skepticism about such an approach.

2.3 A force-theoretic framework (Copley & Harley 2015)

We adopt the force-theoretic framework from Copley and Harley (2015) in which inputs of energy (forces) are represented using functions from situations to situations. We can quickly visualize the difference between this proposal and proposals where events are treated as atoms and (quasi-)mereological joins of atoms. Atomic theories of events (e.g., Higginbotham, 2000; Pustejovsky, 1995; Ramchand, 2008) view events as in Figure 1. In our proposal, by contrast, the Davidsonian argument is the causal glue itself, represented as a function from initial to final conditions; the latter are represented with situation arguments as in Figure 2.

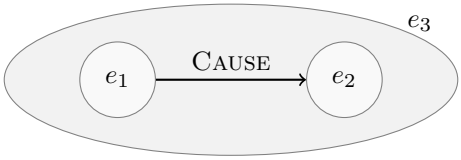


Figure 1: Events as atoms and (quasi-)mereological joins of atoms; e_1 CAUSE $e_2 = e_3$

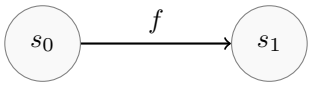


Figure 2: "Events" (forces) as functions between initial and final conditions; $f(s_0) = s_1$

Situations for Copley and Harley (2015) are something like those in situation semantics (Barwise and Perry, 1983). Informally, a situation includes individuals and their property attributions. We adopt Barwise and Perry's distinction between ("real"; in the conceptual model) situations in the world and ("abstract"; linguistic) situation arguments in language; this is a "dual ontology" view.[7] Likewise, we want to make the same distinction for forces. A "real" force is an input of energy. This input of energy is represented in language by a function from an initial situation to a *ceteris paribus* final situation. Copley and Harley's point that "real" forces and force functions in language are not identical is worth underlining: an input of energy is not a function. But this is nothing new; the same point could be, and has been, made about properties in the world and the functions that represent them in language. For example, a

[7] We are not here interested in the question of whether "real" situations and forces are truly real (in the world) or merely in our conceptual model of the world, but we assume the latter.

property such as color is not a function either, despite being represented with a function in our theories of language (Bealer, 1989).

On the whole we are in favor of this picture from Copley and Harley (2015). [8] However we disagree with Copley and Harley's characterization of force functions as functions with a single situation in their domain and a single situation in their range. Instead, both the domain and the range contain many situations. Given an initial situation s_0, we can apply a function f to it to get $f(s_0)$, which is another name for s_1. The function f need not, and really should not, have a singleton domain; we still get a single answer, because we have provided it with a single argument. This is entirely analogous to more familiar functions such as "+": given a single input, it yields a single output.

Following this account, then, f can be identified as a non-singleton set of ordered pairs, not as a singleton set containing one ordered pair of situations. By virtue of its application to a particular situation, f is in a sense "particularized"—simply in that it gets a particular situation argument.[9]

We still need to say a few words about the "final situation" $f(s)$, following Copley and Harley (2015). First, note that it is the causally final situation, not the temporally final situation; this is the key point that will allow us to model entrainment as well as launching. The interpretation of $f(s)$ on the conceptual level is as follows. Suppose that the initial (abstract) situation s_0 corresponds to the conceptual (real) situation σ_0. The (linguistic) final situation $f(s)$ corresponds to the conceptual situation σ_1 that occurs in the case where no force arising, in whole or in part, from outside σ_0, interferes. The final situation on either the conceptual or the linguistic level is thus merely a *ceteris paribus* final situation, as it only occurs if "all else is equal", i.e., if nothing external to σ_0 intervenes (including everything proceeding "normally"). For the English data in this paper, we assume that everything proceeds normally and the *ceteris paribus* final situation actually occurs; this may not be the case in different aspects and/or cross-linguistically.

2.4 FTF: A model for a force-theoretic framework

Here is a force-theoretic model that captures the basic causal structure in Copley and Harley (2015). This model is mostly concerned with the linguistic level, not the conceptual level, for two reasons. First, the dual ontology introduces complexity that is not relevant to the discussion here. Second, in the absence

[8] In addition to references cited by Copley and Harley, Ramchand's 2008 framework also makes the point that an event is a kind of path from the initial conditions (a state) to the final conditions (another state), albeit without the capacity to directly represent entrainment:

> The bounding eventualities of 'initiation' and 'result' are related states: the former being a source, initiational or conditioning state of affairs that gives rise to the process; the latter being the end result of the process (Ramchand, 2008, p. 49).

[9] This is somewhat similar to the $^{\cup}$ operator in Chierchia (1998), except that here we go from kinds to individuals, not kinds to properties; we thank Louise McNally (p.c.) for the insight.

of linguistic evidence one way or the other, we do not really want to pin down how conceptual situations and forces are represented. For example, they could be represented with vectors (Zwarts, 2010; Goldschmidt and Zwarts, 2016); or they could be represented with DRT-like representations (Kamp, 1981; Heim, 1982) along with force-based relations such as EXERT, SUPPORT, ATTACH, etc.; with causal models (Pearl, 2000; Copley, 2022); or some other representation entirely; or with multiple representations depending on the cognitive system in question (visual, sensorimotor, etc).

Likewise, we make no claims about how net forces in the world are calculated at the conceptual level, beyond the commonsense idea that what makes a force a *net* force is that it arises from considering everything in the situation. We only need the fact that net forces are somehow calculated, such that we can reason about what will happen next.

(19) $\langle [\![\ ]\!], U_\sigma, U_\varphi, U_s, U_f, net \rangle$ is a causal structure iff:

a. $[\![\ ]\!]$ is an evaluation function[10]

b. U_σ is a non-empty set of conceptual situations[11]

c. U_φ is a (possibly empty) set of conceptual forces representing inputs of energy.

d. U_s is a non-empty set of linguistic situations such that $\forall s \in U_s, \exists \sigma : [\![s]\!] = \sigma$

e. U_f is a (possibly empty) set of functions from U_s to U_s.

f. *net* is a partial[12] function from U_s to U_f such that $\forall s \in U_s, \forall f \in U_f : net(s) := f$ iff $[\![f]\!]$ is the net force of $[\![s]\!]$.

Note that time is not represented in this model. This is useful, again, because it allows us to account for the idea that launching and entrainment—which differ only in their temporal properties, not their causal relation—are seen as the same by the grammar, at least within the verb phrase.

The above account gives us the basic framework we need to build denotations. Having used the dual ontology to motivate and explain what force functions are, from this point we will background the notion of the dual ontology. In addition, roots, being lexical, should properly take conceptual variables as arguments, since the lexicon resides at the conceptual level. We will not make this move in this paper, however, since it is tangential to our main point.

Finally, a few words about basic eventuality types and agents/causers: Like some but not all event-theoretic frameworks, our framework provides a type difference between stative and dynamic predicates. Stative predicates such as *be in the room, know French* are treated as predicates of situations, type st. Dynamic predicates such as *eat* and *stay* are predicates of force functions, type ft. Following Kratzer (1996), active Voice, when present, introduces the agent/causer

[10] We omit the assignment function and contextual variable on the evaluation function.

[11] The conceptual situations may be structured in a different way from the linguistic situations; we omit any structuring of the conceptual situations here.

[12] The function *net* is allowed to be undefined to account for "still-life" (Copley and Harley, 2014) conceptual situations, i.e. conceptual situations in which no force arises.

as the (main) SOURCE of the energy constituting the force. Unaccusative predicates, of course, correspond to structures lacking active Voice, either through the presence of a dedicated non-active Voice or through the absence of Voice altogether, depending on one's theory.

2.5 FTF+d: Adding degrees

We will now add degrees and scales to the model. Once we integrate them into our force-theoretic framework, we will be able to formalize our proposed meaning for the hypothesized English v head, namely, that an input of energy impels a (perhaps zero) change on a scale.[13]

We assume, following Kennedy and McNally (2005), that scalar roots such as $\sqrt{cool}$ or $\sqrt{straight}$ map their arguments to one of a set of degrees ordered in one direction or another along a dimension (temperature, cost, height, etc.). Thus we will characterize scales by means of *dimension* D; *scale polarity* P which characterizes the direction of ordering, and which can be either $>$ or $<$; and *quantization* Q, following Kennedy and Levin (2008). We use either the set of reals ($\mathbb{R}$, for non-quantized) or the set of integers ($\mathbb{Z}$, for quantized). A scale $\mathbb{S}$ is a pair $\langle D, P_Q \rangle$ where D (dimension), P (scale polarity), and Q (quantization/number set), have possible values as in Figure 3.

Property	Variable	Possible values
dimension	D	*temperature, cost, extent, distance...*
scale polarity	P	$<, >$
quantization (number set)	Q	$\mathbb{R}, \mathbb{Z}$

Figure 3: Properties that characterize scales

P_Q is an ordering relation, i.e., a set of ordered pairs of degrees, which serves to order the set of degrees. Let's consider the positive scale polarity cases first. *Non-quantized* or *dense* scales, as in (20a), are measured in degrees that have values isomorphic to the real numbers between 0 and 1 . *Quantized* scales, as in (20b), are measured in degrees that are isomorphic to the integers between 0 and 1 (i.e., there is just 0 and 1).

Quantization is going to play the role that "open" and "closed" scales play in e.g. Kennedy and McNally (2005), in a way that we will discuss in a moment, and will be crucial to our analysis of telicity as launching causation in section 3 below. A non-quantized (dense) scale has a ordering relation that has an infinite

[13] In formalizing the idea of dynamicity (input of energy) as related to change in this way, we implement the intuition shared by many scholars in the area, e.g. Dowty (1979), Filip (1993), Filip (1999), verkuyl1989aspectual, Comrie (1976), as cited in Rappaport Hovav (2008), with one major improvement, carried over from our previous work fwh 2015: We recognize that a verb can be dynamic (can describe an input of energy) *without* provoking a positive or negative change on a scale, in the case of verbs of maintaining. Locating the measure of impelled difference in v, and asserting that it is defined even when its value is 0, provides a comprehensive formalization of the intuitive connection between dynamicity, "change" and verbhood.

number of members, while a quantized (non-dense) scale has only one member, namely the ordered pair (0,1). [14]

(20) a. Positive scale polarity, reals (non-quantized):
$<_{\mathbb{R}} := \{\ldots(0,\sqrt{.5}),(\sqrt{.5},.5),(\sqrt{.5},.938),(0,.5),\ldots\}$
b. Positive scale polarity, integers (quantized):
$<_{\mathbb{Z}} := \{(0,1)\}$

There are negative scale polarity versions of the scales in (20), with a decreasing ordering from from 0 to -1. In other words, a negative ordering, as in the case of, e.g., $\sqrt{empty}$, is represented not by mapping the least degree to 0, but by mapping it to -1. These negative scale polarity orderings are given in (21):

(21) a. Negative scale polarity, reals (non-quantized):
$>_{\mathbb{R}} := \{\ldots(0,-\sqrt{.5}),(-\sqrt{.5},-.5),(-\sqrt{.5},-.938),(0,-.5),\ldots\}$
b. Negative scale polarity, integers (quantized):
$>_{\mathbb{Z}} := \{(0,-1)\}$

The orderings in (21) will be used for "negative" change-of-state predicates, as we will see shortly in section 3.

In using the novel negative scale polarity orderings in (21), we are reconceptualizing the nature of negative ordering. Kennedy and McNally (2005) reverse the scale to indicate that $\sqrt{hot}$ and $\sqrt{cold}$ are on the same dimension but are oriented in different directions. So, for them, $\sqrt{hot}$ would have a positive-directed ordering on the reals from 0 to 1 as in (21a), but $\sqrt{cold}$ would have a negative-directed ordering on the reals from 1 to 0. Here, instead, for dimensions given by adjectival roots, we wish to leverage the concept of a "home" value contextually mapped to 0, where a pair of antonymic roots represents "more" and "less" respectively from the home value.[15] With a positive scale polarity, home is the lowest number in the order; with a negative scale polarity, home is the highest number.[16]

Why make this move? First, we think it is useful to keep "zero" as a de-

[14] The insight that two-point scales are useful in representing a subset of telic events has been suggested in the analysis of achievement predicates by Hovav and Levin (2014) and Rappaport Hovav (2008) following a proposal by Beavers (2007). Here, we generalize the idea to all telic predicates, both accomplishments and achievements, and relegate the distinct Vendlerian profiles of the two categories to the conceptual component. Indeed, we think adverbials such as *halfway* reset the 1 point of the formal scale, now picking out the conceptual halfway point, analogously to the way that any other measure phrase, e.g. *two cups of oatmeal*, maps to 1.

[15] Our proposal may seem at first too similar to Kennedy's comparisons of divergence such as *sharp/flat*, which as he points out, do not behave similarly to other gradable antonym pairs. Our position is that "ordinary" adjectives differ from comparisons of divergence in the lack of a exact value for the "zero" point that is the same for positive and negative polarities.

[16] If we wanted to delve further into the cognitive basis of grammar, we could point out that this setup maps pretty well to increases versus decreases of energy for antonym pairs such as hot (energy must be put in) and cold (energy must be lost), high (must put energy in) and low (energy must be lost), again from a contextually given home. This is not true for all antonym pairs but it suggests a motivation for having negative numbers in our formal system: to model decreases as well as increases in energy from something that feels like a home value.

ictic home to unify the denotation of the single verbalizing head. Second, we recognize Kennedy's 2001 point that cases of "cross-polar anomaly" as in (22a) pose a problem for theories that take opposing polarities of scales to refer to the same degree points. The issue he raises is that since (22b) is true, (22a) should be equivalent to (22c), which is equivalent to (22d), which is equivalent to (22e); but (22e) should not be equivalent to (22a).

(22) a. ?Alice is shorter than Carmen is tall.
b. Carmen is taller than Alice iff Alice is shorter than Carmen.
c. the degree to which Alice is short $\succ_{\Phi short}$ the degree to which Carmen is tall
d. the degree to which Alice is short $\succ_{\Phi short}$ the degree to which Carmen is short
e. Alice is shorter than Carmen.

Kennedy argues: "The conclusion to be drawn from this discussion is that within a model in which positive and negative degrees are the same objects there is no means of distinguishing between them in a way necessary to achieve the desired result [...] Kennedy (2001, 39). His solution is to jettison the intuitive idea that degrees are points, in favor of treating them as (different) degree-intervals. Our solution is to keep the idea that degrees are points on a scale, but to map them to different numbers, namely positive vs. negative numbers. This move also entails that we don't need to model intuitive differences associated with verbs as formal differences between differences, which to us seems unintuitive.

We posit, accordingly, that in *Carmen is taller than Alice*, the comparative uses a height scale that sets the deictic home "zero" to be the degree to which Alice is tall. This ensures that Carmen and Alice both have non-negative degree-points of height. With *short*, Alice's degree of height is on the negative side of zero and Carmen's height is also represented by a negative degree-point.

Furthermore, using negative numbers in this way for negative scale polarity will prove useful for degree achievement verbs to make sure that changes happen in the right direction; see section 3 below.

The combination of negative numbers and the quantized/non-quantized distinction yields the following meanings for canonical antonym pairs:

(23) a. *x is hot*: x projects a degree on the hot (positive) side of the temperature scale
b. *x is full*: x projects a (the sole) degree on the full (positive) side of the volumetric scale of the container, namely 1
c. *x is cold*: x projects a degree on the cold (negative) side of the temperature scale
d. *x is empty*: x projects a (the sole) degree on the empty (negative) side of the volumetric scale of the container, namely -1

Now, returning to morphosyntax, there are some choices to make about how to formally represent the relationship between roots and scales. We adopt one that seems the most intuitive to us given the compositional constraints imposed

by the structural positions that roots occupy.

Scalar roots characterize scales as in Figure 3:

(24) Scalar roots
   a. non-quantized positive ordering: e.g., $\sqrt{hot} : \langle D_{temp}, <_{\mathbb{R}} \rangle$
   b. quantized positive ordering: e.g., $\sqrt{full} : \langle D_{temp}, <_{\mathbb{Z}} \rangle$
   c. non-quantized negative ordering: e.g., $\sqrt{cold} : \langle D_{temp}, >_{\mathbb{R}} \rangle$
   d. quantized, negative ordering: e.g., $\sqrt{empty} : \langle D_{temp}, >_{\mathbb{Z}} \rangle$

A single root can characterize different scales in different instances, as we will see below in section 3. We will also use "$\mathbb{S}_{\sqrt{root}}$" as shorthand to cover all of these root mappings when the identity of the root is not at issue.

The way we implement the open/closed contrast as involving non-quantized vs. quantized scales suggests that this system can operate without requiring an analogue to Kennedy's 2007 principle of Interpretive Economy as applied to closed-scale predicates (and see also Syrett et al. (2010)). Kennedy wants to understand why predicates like *full/empty/straight*, in combination with **pos**, do not denote 'has a conventionalized degree of fullness/emptiness/straightness', but rather point to the maximal degree on their respective scales. He proposes that a principle of Interpretive Economy in combination with the **pos** operator prioritizes lexical standards over contextually-set standards to account for this property. Since in our treatment, closed-scale predicates' scales contain only a single degree other than zero, we do not need a principle to select from an array of possible values; they will denote the endpoint of their scale by necessity.[17]

Now, to integrate degree-talk with force-talk, we will use a universal measure function as in (25). We call it "universal" because it is not associated with a particular root, as in, e.g., Kennedy and McNally (2005); Kennedy and Levin (2008). The reason we prefer not to associate it with roots themselves is because we want to reserve root meanings to characterize the scale, and our intuition says that there perhaps should be only one measure function which operates with all scales, but nothing hangs on this choice.

(25) Universal measure function:
For any entity x, situation s, scale $\mathbb{S}$: $\mathbf{m}(x)(s)(\mathbb{S})$ = the degree that x projects on $\mathbb{S}$ in s

For the hypothesized unified verbal head meaning, we use a variant of Kennedy and Levin's 2008 measure of change ((16) above). Consider a type *sd* predicate p, entity x, and scale $\mathbb{S}$ such that $p = \lambda s \,.\, \mathbf{m}(x)(s)(\mathbb{S})$. We define $\Delta_s(p_{sd})(f)$

[17] One observation of importance in the literature on closed-scale gradable adjectives is that when they are used in comparative constructions, no entailments related to the endpoints of the scales that they name are observed. That is, Mary can be taller than Bill without actually meeting the standard for tallness–she can be short but still be taller than Bill. Our categorical-scale proposal for the denotation of these predicates does not admit such open-ended uses; we assume that when these predicates compose with the comparative degree morphology, they are coerced to an open-scale denotation, yielding a scale with the dense, unbounded degree ordering that the comparative requires.

as the difference between the degree to which a p of type sd holds in s (where $p(s) \mapsto 0$, i.e. $p(s)$ maps to the degree 0)[18] and the degree to which p holds in $f(s)$. This is what we will call the "measure of impelled difference", or the "measure of difference in p impelled by f from s", which forms the heart of the denotation of unified dynamic v.[19]

In (26) below, the Δ_s notation is for convenience only so that we can more easily follow the meaning of v going up the tree by following the instances of Δ_s. For ease of reading, descriptions of degrees will be written with a dotted underline, and descriptions of (impelled) differences between degrees will be written with a solid underline. These underlines are also just a convention for ease of reading and are not a necessary part of the equations.

(26) Measure of difference in p impelled by f from s (note: $\underdot{p(s)} \mapsto 0$):

$$\underline{\Delta_s(p_{sd})(f)} := \underdot{p(f(s))} - \underdot{p(s)}$$

This measure of impelled difference measures the difference between the degree named by $p(s)$ and the degree named by $p(f(s))$.[20]

Then the hypothesized unified meaning of the v head for dynamic verbs gives a measure of impelled difference as in (27). That is, v takes a type sd predicate p and a force and returns the difference in p that occurs between s and $f(s)$, i.e., as a result of f. We assume that aspect will be of type $\langle fsd, st\rangle$, conveying that there is such a force as the vP describes in the situation in question.

(27) Unified dynamic v:

$$[\![v]\!] = \lambda p_{sd} \lambda f \lambda s\,.\, \underline{\Delta_s(p)(f)}$$

Except for the use of forces rather than events, this unified meaning corresponds rather well to the verb meaning from Kennedy and Levin (2008) and Kennedy (2012), in that participation in an event (here, a force) causes the change of a degree on a scale. Recall, however, that the use of force functions here instead of event arguments is not merely the substitution of the letter f for the letter e. With force functions come the benefits discussed in Copley and Harley (2015) and alluded to above: namely, the ease of representing *stay* and activities as entrained causation, as well as a simple event-kind to event-individual mapping.

[18] We do this as an notational alternative to Kennedy and Levin's 2008 solution of deriving scales by resetting the "zero" point of the scale to be the value at the beginning of the change. Their solution is elegant in their framework, but implementing it in our framework in the analogous way seems less elegant:

(i) $\lambda p \lambda f \lambda s\,.\; \mathbf{m}(x)(f(s))(\mathbb{S}_{\sqrt{root}, \mathbf{m}(x)(s)(\mathbb{S}) \mapsto 0}) - \mathbf{m}(x)(s)(\mathbb{S}_{\mathbf{m}(x)(s)(\mathbb{S}) \mapsto 0})$

[19] Unlike Kennedy and Levin's 2008 measure of change, ours will be defined even when the difference is zero, to account for verbs of maintaining such as *stay*; all that is needed is that the two arguments of the difference function be themselves defined, i.e. they have values.

[20] The right side of (26) is a degree interval rather than a condition on $p(f(s))$ and $p(s)$. The reason for this is that for cases such as *heat the soup from 30 degrees to 100 degrees* (and see (30) below), the information about the degrees $p(f(s))$ and $p(s)$ must be available up to the height of the adjoined degree-specifying phrase.

Also, as we will see, the measure of impelled difference will serve as a useful formalization of the concept of a PATH argument in predicates of directed motion (see, e.g., Jackendoff (1992), Verkuyl and Zwarts (1992), and Ramchand (2008)).

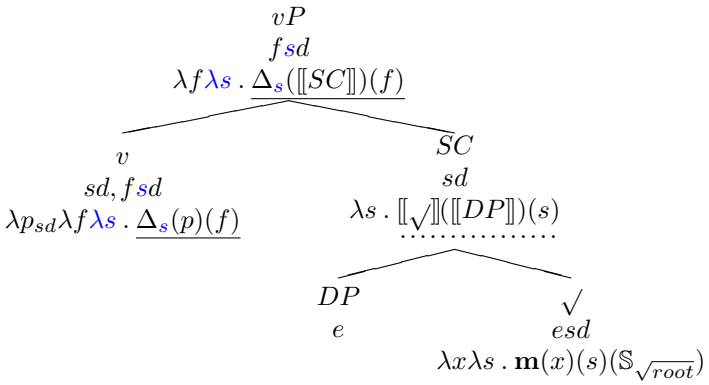
In the remainder of the paper, we consider several major classes of dynamic verbs in turn, showing how this unified denotation of v can integrate with the extant understanding of their syntax and semantics, beginning with change-of-state verbs.

3 Change-of-state predicates

First we will model change-of-state predicates. When the scale is quantized, telicity (launching) arises. When the scale is non-quantized, and nothing else makes it a quantized scale (we will see how this could happen below), atelicity (entrainment) arises.[21]

When adjectival roots form the basis for change-of-state-denoting verbal structures, they compose structurally as in (28), regardless of whether the adjective is associated with a quantized or non-quantized scale.

(28) Change of state predicate (telic or atelic)



The scale $\mathbb{S}_{\sqrt{root}}$ is provided in one of the ways given in (24), depending on the identity of the root, for instance $\sqrt{hot} : \langle D_{temp}, <_{\mathbb{R}} \rangle$, or $\sqrt{empty} : \langle D_{temp}, >_{\mathbb{Z}} \rangle$.

We will look at both the non-quantized (atelic, entrainment) quantized (telic, launching) cases. First, using the root $\sqrt{hot} : \langle D_{temp}, <_{\mathbb{R}} \rangle$ to provide the scale,

[21] There are verbs whose roots have the same properties as the independent closed-scale and open-scale adjectives, such as *melt* (closed-scale roots with no underived adjectival form) or *carve* (on the affected-object reading, not the creation reading) and *curve* (open-scale roots with no underived adjectival form). The independent existence of the predicate as an adjective is not relevant to the semantic analysis proposed here. The morphosyntactic question of why some such roots surface as zero-derived adjectives and others require participial marking (*carved, curved, melted/molten, mowed/mown*), is immaterial; see Embick (2003) and Nissenbaum (2015) for discussion of these questions.

a vP like v *heat the soup* gets the following derivation ("FA" = Functional Application):

(29) $[\![v]\!]$ ($[\![$heat the soup$]\!]$)

$= [\![v]\!](\lambda x \lambda s\,.\,\mathbf{m}(x)(s)(\mathbb{S}_{\sqrt{hot}:\langle D_{temp},<_{\mathbb{R}}\rangle}))([\![$the soup$]\!])$ (24)

$= [\![v]\!](\lambda s\,.\,\mathbf{m}([\![$the soup$]\!])(s)(\mathbb{S}_{\sqrt{hot}:\langle D_{temp},<_{\mathbb{R}}\rangle}))$ FA

$= [\lambda p_{sd} \lambda f \lambda s\,.\,\underline{\Delta_s(p)(f)}](\lambda s\,.\,\mathbf{m}([\![$the soup$]\!])(s)(\mathbb{S}_{\sqrt{hot}:\langle D_{temp},<_{\mathbb{R}}\rangle}))$ (27)

$= \lambda f \lambda s\,.\,\Delta_s(\mathbf{m}([\![$the soup$]\!])(s)(\mathbb{S}_{\sqrt{hot}:\langle D_{temp},<_{\mathbb{R}}\rangle}))(f)$ FA

So, the denotation at the vP node takes a force function f and returns the difference between the degree to which the soup is hot in s and the degree to which the soup is hot in $f(s)$. The vP with this denotation will contribute to a true sentence just in case the measure of impelled difference is defined, i.e., $p(s)$ and $p(f(s))$ have values.

Figure 4 illustrates what happens when a non-quantized scale is used. Consider how the measure of impelled difference changes in time during a successful heating. We will assume that the root $\sqrt{heat}$ requires the theme to undergo an increase in heat. The increase happens while the force is being applied, so this is entrainment; from the moment that any increase in heat has occurred, it counts as a successful heating. The atelic reading is consequently acceptable, from the time when any difference in heat has occurred, and remains acceptable throughout the heating.[22]

We underline again here the fact that s and $f(s)$ are to be individuated causally, not temporally. Both s and $f(s)$ have run times that correspond to the whole change (which is also the whole time that the energy is being input). The way this works for the situation s is that it corresponds to the (real/conceptual) situation from which the (real/conceptual) force arises, and f returns the situation $f(s)$. The degree that x projects on the $\mathbb{S}_{\sqrt{root}}$ scale in s is 0 and continues to be 0 even though the run time of s lasts through the

[22] A reviewer notes that Bobaljik (2012) suggests, based on morphological evidence, that deadjectival degree achievements always contain a comparative operator, thus explaining why such verbs are always based on the suppletive comparative form (*to better/*to gooden; to worsen/*to badden*) noting that such an analysis is also helpful in understanding the atelic readings that are always available with these predicates) However, no comparative morphology is visible in most such deadjectival degree achievements (*to fatten/*to fatter(en); to warm/*to warmer*, casting doubt on the idea that they contain a literal comparative head; neither is it possible to build verbs containing other degree morphology, e.g. superlative or even positive (see Kennedy and Levin (2008) for an argument against the latter idea). Instead, we follow an alternative suggestion of Bobaljik's (205-206): that the verbalizing element (here v) contains a version of the relevant morpho-syntactico-semantic content that is the trigger for suppletion, e.g. a difference function as laid out in Kennedy and Levin (2008). It should be clear that our denotation for v introduces comparable content, which we propose is what conditions the insertion of the suppletive form in the relevant cases. Note that this entails that in the verb at least, the *-er* portion of e.g. *to better* is not itself a comparative morpheme, but instead is reanalyzed as part of the suppletive root, contra Bobaljik.

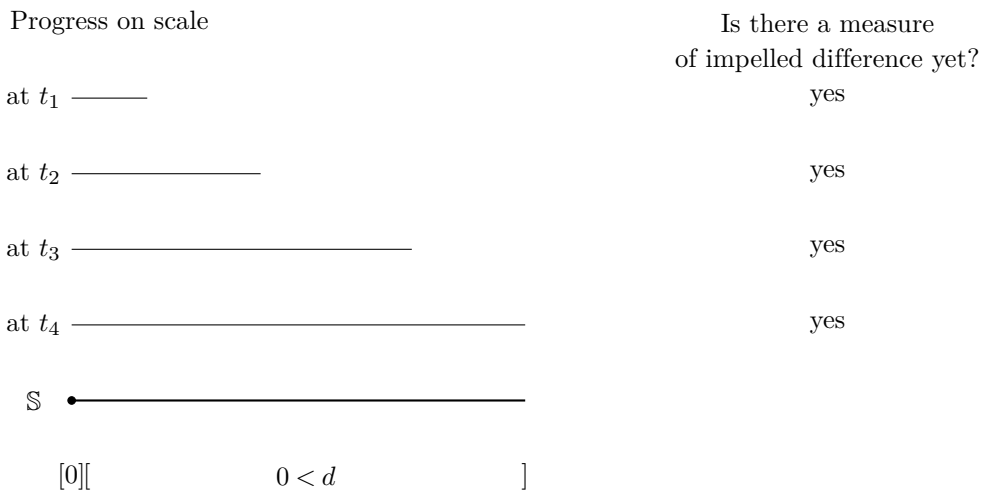


Figure 4: Non-quantized scale root: Atelic reading

whole change, since s represents the situation that would occur if the input of energy that arises from it were (somehow) not applied. In this way we get a kind of counterfactuality—indeed, since we are talking about causation, it would be surprising if we didn't end up with some notion of counterfactuality.[23]

Likewise, the situation $f(s)$ also has a run time that lasts as long as there is a defined measure of impelled difference. The degree achieved on the scale changes through time, but as far as the denotation in (29) is concerned, all that matters is that the measure of impelled difference has a value; and so it does, throughout the change.

~~A question at this point: Individuating two causally related situations in this way seems difficult.~~ If s takes the initial projected value (namely 0) as its value throughout the change, couldn't we just take a more traditional tack and say that there is an initial situation s which occurs when the degree is 0, and thereafter there is a final situation which occurs throughout all the rest of the times? (See Ramchand's *INIT* head, as well as, arguably, Kennedy and Levin's $init(e)$.)

No. Under our assumptions, making s simply the initial portion would mean that the input of energy is only initial, and this is just not true. The only other way we can see to make s only initial would be to treat activities as super-dense semelfactives, a bit reminiscent of Smith (1991, 1999)[24], where at each minimal

[23] In case this is a concern: It is perfectly possible to have a notion of counterfactuality that is not expressed with possible worlds. See Copley and Wolff (2014) for discussion.

[24] Smith (1999, p. 502): "The potential endpoints of Activities derive from the feature of dynamism. Dynamic situations are contingent upon energy. In the world that we know energy requires a source, and we expect dynamic situations to begin and end with the onset and cessation of energy. In this sense the dynamism of a situation brings with it the assumption of an initial endpoint, and the possibility of an eventual final endpoint."

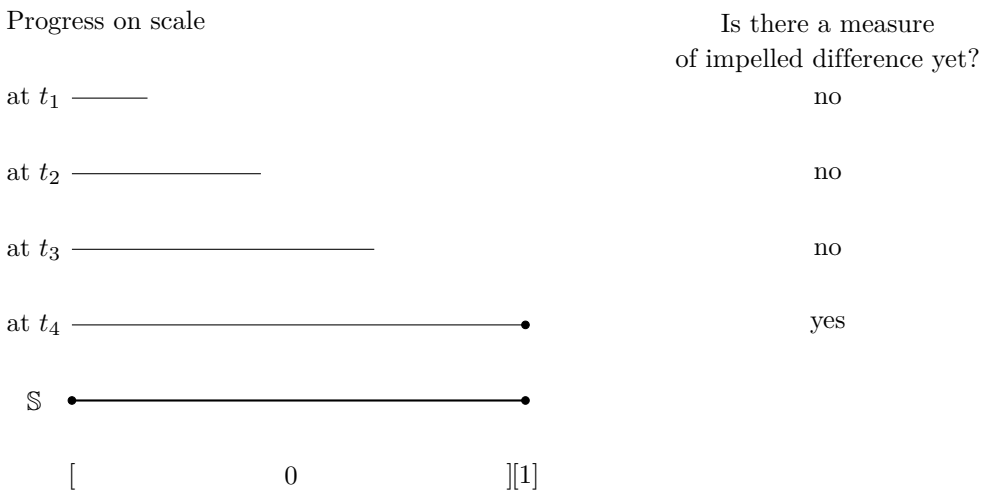


Figure 5: Quantized scale root: Telic reading

perceptible result, a new initial situation is identified and a new result situation occurs. We think this would be possible with our framework, though we have not pursued it here, in part because of a second problem: Namely, treating *s* as only initial breaks the successful force-dynamic analysis of *stay* in Copley and Harley (2015). This is because, given that there is no change, in *stay*-type contexts, there can be no identifiable temporally final situation because the degree remains 0 throughout (recalling that the final situation is defined as occurring when the degree is no longer 0). For these reasons, we think that individuating situations causally, as discussed above, is the correct solution.

Now consider the root $\sqrt{full}$. Its quantized ordering has only one ordered pair in it, namely (0,1). Thus, the measure of difference only gets a referent at all when the endpoint 1 is reached. This is shown in Figure 5. In effect, the measure of impelled difference is only allowed to measure the maximum impelled difference, not any of the others we pass along the way.

Like Kennedy and Levin's theory, our theory can address the major properties of telicity and atelicity in degree achievements that they identified: First, roots can, but do not necessarily, contribute endpoints; they do so if the scale they characterize is quantized. Unbounded readings in this account will be derived by coercion to a dense-scale denotation, as outlined in footnote 17 above. We think this has the advantage that in this approach there will be no need for a Principle of Interpretive Economy, since in positive or telic contexts, the adjective's quantized scale allows only a single degree for truth-making, and in comparative or atelic contexts, the adjective is coerced to refer to a different, dense scale.

Also, in line with the Kennedy and Levin (2008) analysis, it is still the case that with non-quantized scales, any detectable degree change in a positive di-

rection along the scale suffices to satisfy the predicate. This state of affairs corresponds to atelicity. If the root provides a quantized scale, however, a maximum degree is supplied that must be reached for the predicate to be satisfied. One major difference between their account and ours is that for them, atelicity is about what happens at the end of the event, and for us, atelicity is about having the cause and the result occur together.

It is worth mentioning here that the choice we made to treat negative scales as going from 0 to -1, instead of from 1 to 0 as in Kennedy and McNally (2005), allows us to capture the fact that a positive scale polarity corresponds to a positive measure of impelled difference, and a negative scale polarity corresponds to a negative measure of impelled difference. That is, the thing we want to capture is that you can't make something colder using the $\sqrt{hot}$ scale, nor can you make something hotter using the $\sqrt{cold}$ scale. This fact follows from the provision in the definition of the measure of impelled change that $p(s) \mapsto 0$: since we start at zero, and the only degrees on the $\sqrt{cold}$ scale are negative, a negative change is the only change you can make on that scale. (This is not an issue for quantized scales, which admit only one possible change, namely from zero to 1 (positive) or -1 (negative).)

Before closing out the section on change-of-state predicates, we would like to say something about how a maximum endpoint can be externally given by a *to*-phrase, where *to* has the denotation given in (30), and a vP such as *heat the soup to 100 degrees* has the structure shown in (31).[25]

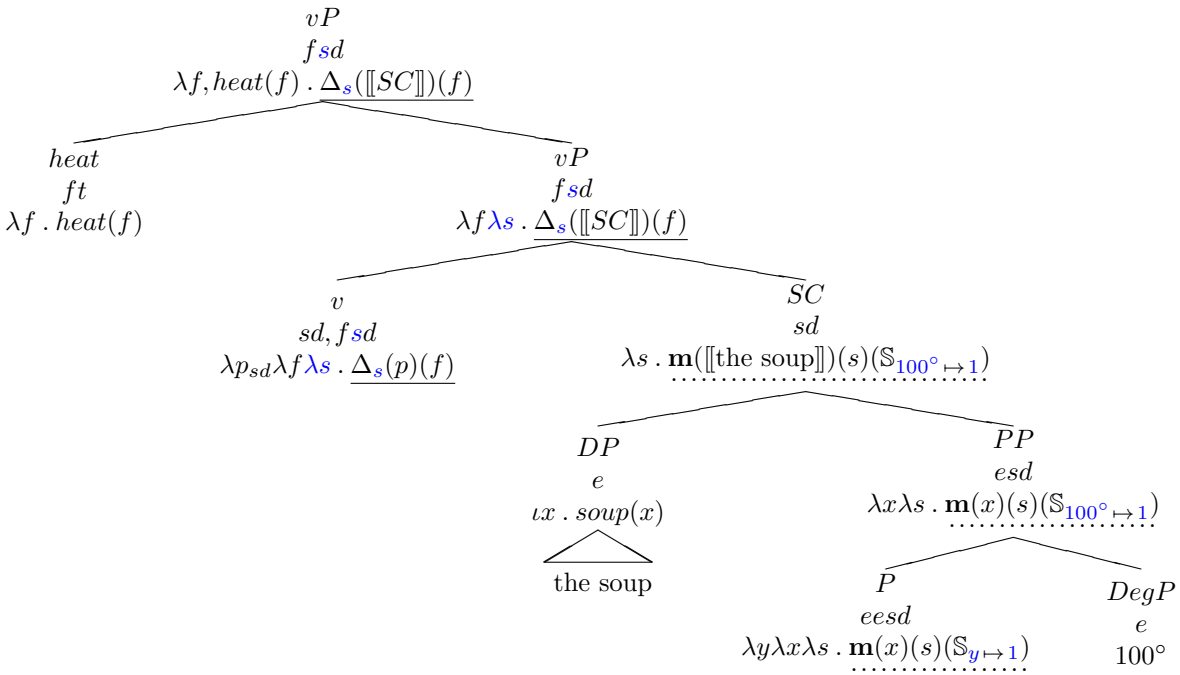
We use the notation "$\mapsto$" to map the referent of a degree phrase to the degree 1. A scale $\mathbb{S}_{x@y \mapsto 1}$ is for example a quantized scale whose endpoint corresponds to the case where x is at y. The denotation for *to* uses this scale (see, e.g. Zwarts and Winter, 2000; Zwarts, 2005, 2008; Beavers and Koontz-Garboden, 2020). We will assume that when an endpoint is thus specified, the resulting scale must use $\mathbb{Z}$ as its number set, resulting in a quantized/categorical scale, even if the root on its own characterizes the scale as non-quantized.

(30) a. $[\![to]\!] = \lambda y \lambda x \lambda s \,.\, \underline{\mathbf{m}(x)(s)(\mathbb{S}_{x@y \mapsto 1})}$

The structure for e.g. *heat the soup to 100 degrees* is given in (31) below:

[25] For *heat the soup 100 degrees*, see footnote 33 below.

(31) heat the soup to 100 degrees



In this tree, the scale is no longer fully described by the root, which is composed as an adjunct to vP rather than the complement to v. The PP complement to v provides the dimension and the quantization of the scale, while the root echoes the dimension and provides the scale polarity (with a compositional caveat to be discussed below). This general line of attack, in which roots can compose in low or high positions, was developed in Copley and Harley's (2015) force-theoretic framework, building on ideas in the event-structural literature. So far, though, we are not quite yet in a position to semantically compose $\sqrt{heat}$ above v in this structure. In the next section, we see that the interpretation of the root in this location is the same as what we will need for incremental theme predicates, to which we turn now.

4 The incremental theme predicate class

4.1 Predicates of creation and consumption

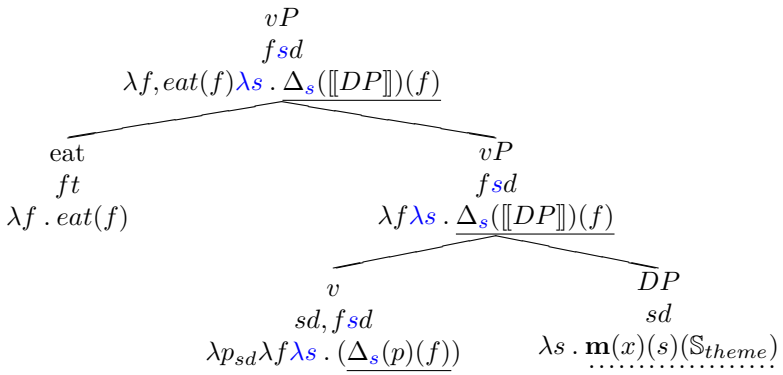
Having treated change-of-state verbs, we move on now to incremental theme predicates, which include predicates of creation such as *write poetry/a poem* and predicates of consumption such as *eat soup/a bowl of soup*. We are still following in the footsteps of much literature, including Verkuyl (1972); Tenny (1987, 1994); Verkuyl and Zwarts (1992); Verkuyl (1996); Krifka (1989, 1992);

Borer (1994, 2005a); Wechsler (2005); Rappaport Hovav (2008); Levin and Hovav (2010); Kennedy (2012); Kardos (2012, 2019b); Beavers (2013); Beavers and Koontz-Garboden (2017). There are two robust results from this literature which interest us here. First, that degrees are used to describe the extent of the incremental theme that is created or consumed; that is, the measure is contributed by the theme or close to the theme (see Kennedy, 2012). Second, that the verb does not itself lexicalize a measure of change (for us, a measure of impelled difference) but is rather a simple predicate of events (Gawron, 2005a; Rappaport Hovav, 2008; Levin and Hovav, 2010).

Both of these insights fit naturally into the picture we are building with a single v head that requires of its complement, but does not itself contribute, the measure function. For the theme, we can follow Kennedy (2012) and others in saying that in change-of-state structures, the element that contributes the measure function and the scale is the small clause, while in incremental theme structures, the measure function and the scale are contributed by the object. As for the insight that incremental theme verbs are predicates of events: These verbal roots have long been recognized to contribute manner to schemata of verbal meaning, as in, for example, Levin and Rappaport Hovav's Lexical Conceptual Structures (Levin and Rappaport Hovav, 1995). In our framework, with a single verbal head, such fundamentally modificational content is quite restricted in its potential distribution; it must compose with a projection of the v head. Since it is not the complement, it therefore attaches just above v.

Taken together, these two ideas give us the structure in (32) for incremental theme predicates:

(32) Incremental theme structure



To interpret this structure, quite a lot more needs to be said on both the theme[26] and the verbal root–including that for the latter we still need to fulfill the promise we made above that we would explain the meaning of the root in the high position. We take these in turn now.

[26] For cases where the theme is absent, e.g. *Mary ate/read/wrote*, see section 5 below.

4.2 The incremental theme

The incremental theme characterizes an extent scale (Levin and Hovav, 2010). The degree it projects in the causally initial situation s on the relevant extent scale is always 0, whether the scale has positive polarity (predicate of creation) or negative polarity (predicate of consumption), exactly as for the change-of-state cases. It might seem counterintuitive to start from 0 for a predicate of consumption–after all, the referent of the incremental theme has a certain extent in the world at the beginning of the event. However, all the reasons we gave in section 3 above still apply, and calling a certain formal degree "zero" in order to calculate a relative change has nothing to do with the actual extent of the referent of the theme.

Quantization or the lack thereof figures into the computation of telicity of incremental theme predicates in a familiar way, very similar to open vs. closed adjectival scales in changes of state (Kennedy and McNally, 2005). Non-quantized objects provide a non-quantized scale. Quantized themes provide a quantized scale. This yields launching in the same way that we detailed above for changes of state, because their quantized nature means that the relevant degree, either 1 or -1, is not reached until the end of the change.

As has been convincingly argued (Verkuyl, 1993; Tenny, 1994; Krifka, 1989, 1992; Borer, 2005b; Kennedy, 2012; Beavers, 2013; Kardos, 2019a, a.o.), determiners are very relevant to measurement; they could host our universal measure function. In our system, where an incremental theme root characterizes a scale (as motivated by the telicity difference between e.g. *to spawn* and *to calve*, see Harley (2005)), we also allow nominal functional structure, including determiners, to impose their own quantization properties. We will not analyze the compositional meanings of different themes with different determiners. For us, what matters is that the theme is of type sd in order to serve as the complement of v, and that both DPs and roots can provide the quantization value of the scale.

4.3 Predicate Restriction

Now we will finally see how to interpret the root in the high position, by making an adjustment to Predicate Modification.

The composition of the high root with the v-headed projection is, essentially, that of Predicate Modification. But recall that the type of our v head is sd, fsd, and that type f is the type that represents inputs of energy (forces). The type of the vP node is then type fsd: Given a force and a situation it returns the measure of difference impelled by that force starting from that situation. As we have said above, we assume that the high root modifies forces. So in our framework, these verbal roots are type ft.

Thus we have a type problem, in that we need to compose a type ft predicate with a type fsd predicate. That is, the type ft function must provide a restriction on the kind of situation that is fed to the type fsd function. So, we want the input of energy that causes the creation or consumption of the theme

to be a particular kind of input of energy. This seems like a reasonable thing to want to do.[27]

Perhaps the simplest way to do it is to introduce a rule which is a generalization on, and which henceforth replaces, Predicate Modification.[28] Predicate Modification (Heim and Kratzer, 1998) is as follows:

(33) Predicate Modification: If a branching node α has as its daughters β and γ, and $[\![\beta]\!]$ and $[\![\gamma]\!]$ are both of type η,t then $[\![\alpha]\!] = \lambda x \in D_\eta$. $[\![\beta]\!](x)$ & $[\![\gamma]\!](x)$. This formula is of type η,t.

We then generalize on the truth value type to form a new compositional rule that replaces Predicate Modification. We use the comma to introduce a restriction on the lambda operator.

(34) Predicate Restriction: If a branching node α has as its daughters β and γ, and $[\![\beta]\!]$ is of type η,t and $[\![\gamma]\!]$ is of type η,θ then $[\![\alpha]\!] = \lambda x_\eta$, $[\![\beta]\!](x)$. $[\![\gamma]\!](x)$. This formula is of type η,θ.

Predicate Modification can be derived from the special case of Predicate Restriction where θ = t, since λx . $[\![\beta]\!](x)$ & $[\![\gamma]\!](x)$ is truth-conditionally equivalent to λx, $[\![\beta]\!](x)$. $[\![\gamma]\!](x)$.

We propose that Predicate Restriction is the rule of composition corresponding to the syntax of head adjunction as understood by Matushansky (2006). The root, e.g., $\sqrt{eat}$ is adjoined ("e-Merged") to the vP, in the position in which verbal modifiers like adverbs are interpreted. It receives a typical adverbial interpretation (predicate restriction) in this position, which is where it is at LF, but on the PF branch it undergoes further morphological alteration: it "m-Merges" with the v head and surfaces as the verb *eat*. (See also Folli and Harley (2020) for discussion of how this operation derives manner-of-directed-motion constructions.) This allows us to retain a single denotation for the v head, while at the same time being faithful to what is known about the syntax of these verbs. Thus we can now give the compositional derivation of (32) as (35), and composition works as before: just as the SC was the type *sd* complement of v in the change-of-state examples, here the DP is the type *sd* complement of v.

(35) $[\![\text{eat } v \text{ soup}]\!]$

$= \lambda f, eat(f) \lambda s$. $\underline{\Delta_s([\![\text{soup}]\!])(f)}$ (27), (34)

$= \lambda f, eat(f) \lambda s$. $\underline{\Delta_s(\lambda s$. $\mathbf{m}(x)(s)(\mathbb{S}_{\sqrt{soup}}))(f)}$ (24)

[27] After we wrote this, JP Koenig drew our attention to Chung and Ladusaw (2003), which proposes essentially the same rule of predicate restriction, for different data.

[28] Another way, we think, might go through the idea that truth values are themselves a categorical scale, making degrees and truth values the same type. However, in the present case even if a degree on a truth value scale and a degree on an extent scale are the same type, it does not yield the right meaning if we try to combine them with Predicate Modification since the same degree would have to be able to be on both scales. This is formally possible but not what we want.

$$= \lambda f, eat(f) \lambda s \,.\, \underbrace{\mathbf{m}(x)(s)(\mathbb{S}_{\sqrt{soup}})}_{\cdots\cdots\cdots\cdots\cdots} - \underbrace{\mathbf{m}(x)(f(s))(\mathbb{S}_{\sqrt{soup}})}_{\cdots\cdots\cdots\cdots\cdots\cdots} \tag{26}$$

A reviewer notes that DPs with a measure phrase such as *eat two cups of soup* are crucial to account for, drawing attention to the fact that in Kennedy's proposal, *two cups of soup* refers to the *difference* between no cups of soup and two cups of soup. In our theory, if *two cups of soup* were to refer to a difference, then the DP would have to be merged at least as high as v, where we introduce the measure of impelled difference; and this is not at all plausible.

In fact, however, for us *two cups of soup* does not provide a difference, so this problem does not arise. For us, *two cups of soup* provides the *scale* on which the measure function operates—just as *soup* does in (35). While the scale provided by *soup* is non-quantized, the scale provided by *two cups of soup* is quantized, and the value 0 corresponds to the initial extent of two cups of soup in s. So, the DP is type *sd*: given a situation, it yields a degree on the "two cups of soup" scale. It's worth underlining that for us, incremental themes provide a scale, not a degree or a difference between two degrees on a scale.

4.4 Slopes

We can now turn to the question of why in the denotation in (35) there is nothing explicitly saying that *eat* is a predicate of consumption and not a predicate of creation. That is, there is nothing in our denotation that says that we are consuming the soup, going from our deictic home 0 to degree -1 on the "two cups of soup" scale. This information, as we said earlier, lies with the root $\sqrt{eat}$; it has to be part of what we mean when we write $eat(f)$. But the structure in (35) does not let the root meaning access the type *sd* predicate provided by the small clause because the root is too high. If we were quite determined to put the distinction between creation and consumption in the denotation (as Copley and Harley (2015) implicitly did by having a v_{appear}), we could certainly do so by putting it in flavors of v as follows:

(36) Multiple flavors of v for creation and consumption (not proposed)

a. $[\![v_{creation}]\!] = \lambda p_{sd} \lambda f$, slope($\underline{\Delta_s(p)(f)}) > 0 \lambda s \,.\, \underline{\Delta_s(p)(f)}$

b. $[\![v_{consumption}]\!] = \lambda p_{sd} \lambda f$, slope($\underline{\Delta_s(p)(f)}) < 0 \lambda s \,.\, \underline{\Delta_s(p)(f)}$

This would work because unlike the root, v *is* close enough to the small clause to have access to it. However, positing multiple flavors of v is exactly the many-headed kind of theory that we wish to avoid in this paper, so we will not make this move. Our only option, then, if we wish to tame the Hydra, is to argue that the distinction between creation and consumption does not need to be represented in the denotation; that it is sufficient that it be represented in the root. And in fact, there is an argument that this is the case.

We contend that roots in this position can specify a property of the difference provoked by the conceptual force, and that this property effectively constrains the set of ordered pairs denoted by f. This property we will term *slope*. The argument is similar to the argument that manner individuates event

kinds (Landman and Morzycki, 2003). In the end, it will be both manner and slope that individuate force functions, which are the analogue to event kind arguments in our theory.

Recall the difference between the degree projected by x on $\mathbb{S}$ in s, and the degree projected by x on $\mathbb{S}$ in $f(s)$). If the degree in s is less than the degree in $f(s)$, the measure of impelled difference has a positive slope; if the degree in s is more than the degree in $f(s)$, it has a negative slope, and if the two degrees are the same, it has a zero slope. These options are represented in the graphs in Figure 6.

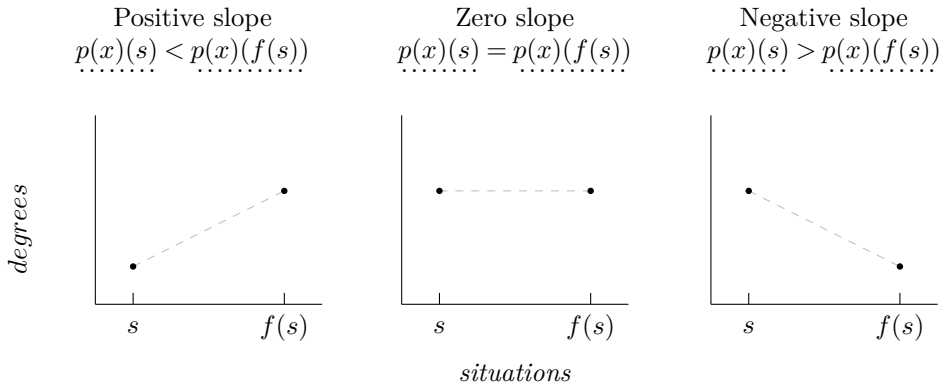


Figure 6: Slopes

We get this idea from Croft (2012) who has proposed that the difference in a qualitative state over time that appears in verb meanings is appropriately modelled with graphs on a Cartesian plane (see also Verkuyl (2019)). Essentially, the slopes of these graphs from the initial point to the final point make the distinction that we are interested in here.[29] Slopes can be positive, representing increase, or negative, representing decrease. Equally, there is the possibility of a zero slope which represents a lack of change. Again, this option will come in handy when we discuss verbs of maintaining below in section 6. We stress that the gray dashed lines in the graphs are there simply to illustrate the notion of slope; the exact paths are not represented in the denotation (though the root

[29] A difference between our formalism and Croft's is that his x-axis is time. We don't make reference to time this low in the structure, so as to capture the grammatical flexibility between launching and entrainment. So, our changes reflect differences along a causal chain, rather than differences through time, and our "x-axis" is made up of discrete situations, namely, s and $f(s)$. Incidentally, using causality instead of time in slopes suggests the outline of an answer to the conundrum of "fictive motion" in stative sentences such as *This road goes to Phoenix* (and see Gawron, 2005b; Talmy, 2010; Deo et al., 2013). These represent differences but not changes, and in our slopes there is a difference without there being change in time; change is exactly difference over time. The fact that such sentences exist (and indeed that any causal statives exist) suggests that our force functions should also be able to be used in the denotations of causal statives. That is, they would still certainly be able to map to forces as we propose here, but they would also need to have the possibility to map to other, non-energetic causal relations as well.

meaning may have something to say about it). This is especially key given that, in cases of entrainment, there will be no "path" over time, rather just a difference between the two values over the same run time.

We will now argue for verbs of incremental change such as *eat*, that the slope is recovered from the root meaning. Because of the kind-denoting nature of force functions, the entities that we use to calculate slope are to be identified with the entities referred to in the complement of v. If this move is correct, we also obviate the need for a rule of composition such as Event Identification (Kratzer, 1996) that does the same job.

As we have argued above (section 2.3), and in contrast to Copley and Harley (2015), our force functions need to refer to sets of ordered pairs of situations. So, for example, a force function f could have as its extension a relation on situations as follows:

(37) $\{(s_{23984478}, s_{44}), (s_5, s_{592874}), (s_{457}, s_{400}), (s_{435}, s_{98303}), \ldots\}$

There are many such relations on situations. Only some of them correspond to *kinds* of inputs of energy, or "force-kinds". But what *is* a kind of input of energy? The answer to this question has to rely on some generalization that our intentional-conceptual system uses to organize inputs of energy. Landman and Morzycki (2003) established that manner is one of the ways kinds of events are organized; this would hold as well for force-kinds in our framework. We propose additionally that forces, i.e. inputs of energy, happen to be classified according to whether they create a positive change on a scale (positive slope), a negative change on a scale (negative slope), or no change on a scale (zero slope). This criterion is akin to any other criterion for classifying force-kinds in the lexicon, such as requiring a participant to be animate.

So, for instance, *eat* picks out inputs of energy that have in common a decrease in the extent of an object (via the action of a mouth, etc.). So the pairs of situations are pairs that reflect such a decrease.[30] We propose that once you have picked out only the $\sqrt{eat}$ force-kind, then for any situation fed to the force function representing that kind of input of energy, there is exactly one object and exactly one scale in that situation that meet the criteria, i.e. that satisfy the verb's selectional restrictions.[31]

(38) *Force function individuation by slope:* A function from situations to situations is a force function (comparable to an "event kind") only if for every ordered pair (s_1, s_2) in the relation is such that there is exactly one entity x and exactly one scale $\mathbb{S}$ such that there is a (positive/negative/zero) difference D (the *slope* of f) such that $D = \underbrace{\mathbf{m}(x)(f(s))(\mathbb{S})}_{\cdots\cdots\cdots\cdots} - \underbrace{\mathbf{m}(x)(s)(\mathbb{S})}_{\cdots\cdots\cdots}$.

[30] We must be careful, however, *not* to interpret the pairs of situations as necessarily occurring sequentially in time, because of cases of entrainment.

[31] Regarding "exactly one": There are a range of familiar solutions to the various possible interaction of plural arguments with event roles, any of which would carry over to our force-theoretic proposal here, see Carlson (1998); Henderson (2012).

This proposal is effectively a version of the individuation of events proposed in Carlson (1998), where events are individuated in terms of their (selected) participants. This implementation of selection is conceptual rather than compositional in character.

A reviewer expresses a concern regarding the formal legitimacy of this move: "[c]an forces (qua functions from situations to situations) really be independently constrained in virtue of how the objects they relate are mapped to completely different values (degrees) by completely different functions (measure functions)?" Our answer is that properties of participants are always fair game for selection by the verb: *eat* requires comestibles, *drink* liquids, *addled* eggs or brains, etc. In our case, because the participant x has the property of projecting a degree on a scale, it's reasonable to think that these degrees are themselves fair game for being targeted by selection. Thus, we are satisfied that verb roots can impose restrictions on degree-related properties of the theme, such as $\mathit{slope}(f)$, which expresses the direction of change in the degree projected on a scale by the participant in question.

The vP node, for its part, conveys that a force impels a difference in the extent of the theme. To combine these meanings, we identify the entity and scale in the root meaning with their counterparts in the complement of v. Given that force functions are constrained as above, there is only one entity and one scale in the root meaning so there is no problem identifying them with the entity x and scale $\mathbb{S}$ introduced by the measure function and the incremental theme. In other words, since we already know from the lower part of the structure that that very same force provokes a degree of difference in the extent of the theme, that is enough to identify the compositionally-introduced linguistic variables with the conceptual variables contributed by the root.

In this way, slopes need only be represented in the verbal root itself. This point generalizes to other roots, such as verbs of maintaining and ditransitive verbs, discussed below in sections 6 and 7 respectively. Slope information is thus introduced via a high-adjoined root, like manner, although we wish to maintain a distinction between the two. So, while roots in this high position can of course also contribute manner, as $\sqrt{eat}$ does, with its negative slope and mouth-related manner information, we treat slope as something distinct from manner, as it can apparently be contributed in the absence of manner, e.g. $\sqrt{make}$, which has a positive slope but leaves manner information to the imagination.[32]

Before we finish with slope, we should underline that slope and scale polarity are not the same, even though both slope and scale polarity can have positive and negative values:

[32]Note that $\sqrt{make}$ is traditionally thought of as a "light verb", which in a "flavors of v" style approach as in Folli and Harley (2005) would mean that it should be treated as a functional element and stand in a paradigmatic relationship with other light verbs. In this account, it behaves no differently than any other vP-modifying root. That is, we do not envision a morphosyntactic class of light verbs; they're just verbs. However, we do envision a fairly precise notion of semantic "lightness" that may be able to characterize the traditional light verbs; in particular, these verbs do not contribute anything more than slope information, and pick out an exceptionally large class of forces.

They take different arguments. Scale polarity expresses a property of a (perhaps singleton) set of ordered pairs, while slope expresses a property of a single ordered pair.

They do not have the same set of possible values. Scale polarity, recall from section 2.5, is a binary distinction that tells us whether the ordered pairs in the ordering of the scale are increasing or decreasing from zero (i.e., whether the first member of each pair is smaller than the second, or vice versa). Scale polarity cannot have a zero value; actually, it is not at all clear what a zero value could even be, given that an ordering of a scale must in fact order the elements of the scale. Slope does admit a zero value; it describes the relationship between two degrees that differ by an impelled difference. Because the two degrees can in principle be identical, zero is a possible slope value.

They are in different places in the structure, and necessarily so. Scale polarity is involved in the characterization of scales, which must be done in the *sd*-type complement of v. Slopes are determined by verb roots which adjoin above v, because they depend for their meaning on a (conceptual) force; thus they only appear at a height from which f is accessible.

Thus, while both slopes and scale polarity compare degrees, they do so in different formal contexts, and this goes along with the fact that they do so in different positions in the tree. Despite these differences, however, there is of course a formal similarity in the positive/negative values of scale polarity on the one hand and slope on the other. They both ensure that any ordered pair of degrees they are given has a first member which is lesser/greater than the second member. This, we will now (finally) see, is key in understanding how a root like $\sqrt{heat}$ can be interpreted high, contributing a slope, as well as low, contributing scale polarity.

Recall that the *vP heat the soup to 100 degrees* has the denotation in (31) above:

(39) $\lambda f, \sqrt{heat}(f) \lambda s\ .$
$\mathbf{m}([\![DP]\!])(f(s))(\mathbb{S}_{[\![DP]\!]@100^\circ \mapsto 1)} - \mathbf{m}([\![DP]\!])(s)(\mathbb{S}_{[\![DP]\!]@100^\circ \mapsto 1)}$

Now that we have Predicate Restriction, we can combine the type ft and type fsd nodes as we adjoin $\sqrt{heat}$ in the high position. The information that $\sqrt{heat}$ contributes there is positive slope and, redundantly, that the dimension is temperature (which we already have from the complement of *to*).

If slope and scale polarity are different, and $\sqrt{heat}$ contributes scale polarity in the low position, how can it contribute slope in the high position? The answer is that it is possible to distill a single meaning for roots like $\sqrt{heat}$, based on the commonality between positive/negative values in scale polarity and slope that we just discussed. This meaning ensures that any ordered pair of degrees it has to deal with is in the right order. In the low position, we are dealing with a set of ordered pairs of degrees, and we get a scale polarity. In the high position, this meaning constrains the single ordered pair of degrees in the slope, we know that the measure of impelled difference on the right side of the function in (39) is positive.

Note that if we had used $\sqrt{cool}$ instead (*cool the soup to 100°*), we would have known that the measure of impelled difference was negative. With either *heat to 100 degrees* or *cool to 100 degrees*, the scale polarity that fully characterizes the scale, is effectively backformed from the slope: If the slope is positive/negative, the measure of impelled difference is positive/negative, and because we know that the degree projected by x on $\mathbb{S}$ in s is necessarily zero, from the definition of the measure of impelled difference, we can conclude that the scale polarity is positive/negative.

4.5 Other incremental theme predicates

We turn now to incremental theme predicates that are not obviously either predicates of creation or predicates of consumption; this class includes predicates such as *paint the wall* and *read the book*. While the wall is not created and the book is not destroyed, the wall and the book still "measure out" the event in the familiar way. For instance, the wall's surface is gradually more and more covered with paint, and the reader('s eyes? mind?) traverses (consumes?) the abstract path defined by the line of textual content that makes up the book. If you mow the lawn, for example, what changes is the extent of *mowed* lawn, not the extent of the lawn *per se*.

Our claim here is that although these are not predicates of literal creation or literal consumption, grammatically speaking they work in the same way as predicates of literal creation and literal consumption. The variation lies in the conceptual interpretation of the extent, not in the grammar. The idea (following, e.g. Dowty, 1991; Jackendoff, 1991) is that there is a interpretation of "extent" that includes both what we will call "literal extents" and what we will now call "metonymic extents". Metonymy, of course, is the phenomenon whereby a DP is used to pick out a subpart of the entity it would normally denote. A metonymic extent is an extent that only represents part of an entity. First we will argue that this is the right way to think about these verbs, and then we will say how our framework accounts for this phenomenon.

To see that these verb are truly members of the incremental theme class, i.e. that the grammar doesn't represent the difference between literal and metonymic extents, note that the object shows similar type restrictions.

First, the object of both literal creation/consumption predicates in (40) and the object of *mow/read* predicates in (41) can be a measure-DP, i.e., they are of type sd.

(40) a. make two quarts of soup
b. eat three spoonfuls of soup

(41) a. mow three square meters of the lawn
b. read five pages of the book
c. walk sixteen miles of the Appalachian Trail

These stand in contrast to the change-of-state class (see our structure for these given in (28) above) which do not allow their object DPs to be replaced with

measure-DPs:[33]

(42) a. *heat three degrees
b. *shorten five minutes
c. *inflate six inches
d. *lengthen seven days

Conversely, and following Kennedy (2012), degree *by*-phrases are possible with change-of-state predicates, as in (43), but are impossible with both literal creation/consumption predicates (shown in (44)) and *mow/read* predicates (shown in (44)):[34]

(43) a. heat the soup by three degrees
b. shorten the talk by five minutes
c. inflate the balloon by six inches
d. lengthen the tour by seven days

(44) a. *make the soup by two quarts.
b. *eat the soup by three spoonfuls
c. *mow the lawn by three square meters
d. *read the book by five pages
e. *walk the Appalachian Trail by sixteen miles

In each of the examples in (44), the apparent entity-denoting DP is actually something that names a measure of difference itself, so there is no room for a *by*-phrase, which would otherwise describe the measure of impelled difference (Bruening, 2013; Carlson, 1998).[35]

So, as far as the type of their object is concerned, the *mow/read* incremental theme predicates are just the same as the literal creation/consumption incremental theme predicates: They have a type *sd* object.

This similarity at the compositional level leaves to the conceptual level the explanation of any difference between literal creation/consumption predicates and *mow/read* predicates. Our proposal is that in literal creation/consumption predicates, the scale $\mathbb{S}_{theme}$ has an extent dimension that relates to a literal extent, while the extent dimension of the scale $\mathbb{S}_{theme}$ in *mow/read* predicates relates to a different kind of extent: a "metonymic" extent.

[33] A reviewer notes that 'difference' measure-DPs are in fact available with this class of degree achievements, as in *heat the soup one hundred degrees*, as long as the object is retained. These are, as far as we can tell, synonymous and interchangeable with the difference measure phrases in *by*-adjuncts (*heat the soup by one hundred degrees*) discussed immediately below, and we suggest that they should be treated as morphological variants of those expressions, likely with a null preposition in place of *by*, and composing with vP in the same way. Indeed, there seems to be some interspeaker variation in acceptability of the *by*-less variant, which is consistent with the idea of lexical variation in the availability of the null P in such cases, analogous to the variation documented for null *to* by Myler (2013).

[34] As Tenny (1994) notes, the Appalachian Trail in *walk the Appalachian Trail* names the path itself. The equivalent of the path in our account is the measure of impelled difference.

[35] This incompatibility is entirely parallel to how *by*-phrases introduce agents in the passive, but are impossible with active Voice, since the agent role is already fully expressed by the external argument.

Literal extents are the kind we are used to thinking about, in which the total physical body of the denotatum corresponds to the dimension of a scale. Metonymic extents are also scales computed from the meaning of the denoted object–specifically, its part/whole structure. The difference between literal and metonymic extents is whether the extent being considered is the whole denotatum or only some subpart of the denotatum. This idea was explored by Jackendoff, who introduced a notion of 3D part/whole structure into his lexical conceptual structures to account for it.

Using such 3D conceptual representations of denotata, we can distinguish literal extents which use the entire volume of the denotatum to create the scale, as in (45a), from metonymic extents.[36] These extents can be, for example, surfaces that are created or consumed, as with *plaster* and *mow*, as in (45b), or lines that are created or consumed, as with *spin* and *trim*, shown in (45c).

(45) a. Volumetric dimension: creation/consumption predicates
b. Areal dimension: e.g. *plaster* (creation of a surface)/*mow* (consumption of a surface)
c. Linear dimension: e.g. *spin (a thread)* (creation of a line)/*trim (a cord)* (consumption of a line)

The constraint that tells you what kind of extent dimension is to be used comes from the verb root. That is, as discussed above, the force function represents a force-kind and the root specifies various properties of the conceptual force and its causally initial and final conditions. The root $\sqrt{mow}$ picks out only the force functions that impel a change on a surface extent, among other things its meaning specifies.

5 Activity predicates

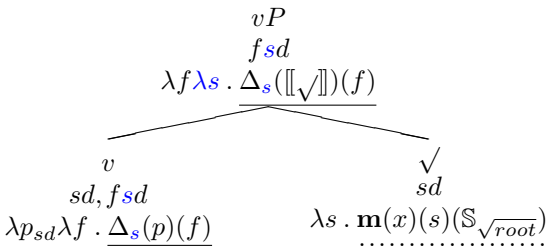
We now turn to activity predicates such as *dance*. As we pointed out in section 2.1, activities had not been analyzed as entrainment in formal theories before Copley and Harley (2015); using our version of their force functions, we can represent them as cases of entrainment. This allows us to treat atelicity in a causal, entrained fashion the same way we treated the atelicity in the variably telic classes.

Following Harley (2005) and Copley and Harley (2015), activities will in-

[36] An issue which is orthogonal to the main discussion here is *figurativity*, that is, whether the extent is the thing (or part of the thing) itself or a representation of the thing as Dowty (1991) suggests. He proposes to conceptualize predicates like *read a book*, *paint a landscape* or *sculpt Napoleon* as involving the creation or consumption of a representation of the denotatum of the object, rather than the object itself. One who sculpts Napoleon creates a representation of Napoleon, not Napoleon himself. It's perhaps worth nothing that such representations can involve the same varieties of 3D conceptual structure as other extents; for example *read a book* might involve consumption of a linear representation; *paint a landscape* a 2D representation, and *sculpt Napoleon* a 3D representation. Verbs that take figurative extent objects also take actual extent objects; one can *read sentences*, *paint a portrait* or *sculpt a figure* without invoking a such a figurative mapping.

troduce abstract entities that are created through the agent's input of energy. So, activity verbs are verbs of creation, and their roots serve as the incremental theme argument. The compositional semantics of the complement of v is exactly the same as for the incremental theme class; syntactically, however, the complement of v is a $\sqrt{}$, not a DP. The root of an activity verb provides the scale, as incremental themes do. (Note that it is necessary for the root to merge low, as the sister of v, given the unified denotation for v we are proposing in this paper: if v doesn't get a measure function to produce an impelled difference from, it cannot be interpreted.) Thus we have entrainment and atelicity in the canonical activity predicates, where the theme is identified by an non-quantized root such as $\sqrt{dance}$ $\sqrt{blood}$ or $\sqrt{spawn}$. Equally, however, we get launching and telicity in the case that the theme is identified by a quantized root such as $\sqrt{calf}$ or $\sqrt{hop}$; these latter roots are the "semelfactive" class (Comrie, 1976; Smith, 1991). In all these cases, remember that the root provides the scale, not the entity argument, as discussed above in section 4.1.

(46) Activity structure



(47)
$$
\begin{aligned}
&[\![v \text{ dance}]\!] \\
&= \lambda f \lambda s \,.\, \underline{\Delta_s([\![\text{dance}]\!])(f)} && \text{(27), (34)} \\
&= \lambda f \lambda s \,.\, \underline{\Delta_s(\lambda s \,.\, \mathbf{m}(x)(s)(\mathbb{S}_{\sqrt{dance}}))(f)} && \sqrt{dance} \\
&= \lambda f \lambda s \,.\, \underline{\mathbf{m}(x)(f(s))(\mathbb{S}_{\sqrt{dance}}) - \mathbf{m}(x)(s)(\mathbb{S}_{\sqrt{dance}})} && \text{(26)}
\end{aligned}
$$

It is also worth noting that these roots can appear in transitive structures as well, with cognate *(dance a dance)* or hyponymous objects *(dance a tango)*. In either case, they are garden-variety verbs of creation, where the object behaves as an incremental theme and measures out the event. The analysis for such cases is thus simply the incremental theme analysis in (32) above, with the root (e.g. $\sqrt{dance}$) in the high, v-adjoined position, exploiting the option to merge roots in different locations in the structure, where they are interpreted as imposing conditions on the force function that are characteristic of e.g. dancing.

We note that there are apparently no activity or semelfactive predicates with a negative slope. That is, there is no root whose meaning in this structure involves a decrease in the abstract entity. There is no root in the high manner

position that would be expected to provide a slope; the default slope provided instead seems to always have to be a positive slope.[37]

In the context of our goal of taming the verbal Hydra, this solution to the problem of activity predicates is exactly what allows us to eliminate primitive DO from the inventory of verbal heads and replace it with a single causal head. Key to accomplishing this is the move from temporally-based billiard-ball thinking about events causing other events to a more expansive vision of causation where effects can follow *causally* from causes without having to (entirely) follow them *temporally*.

In discussions of Vendlerian event classes in neo-Davidsonian frameworks, it was clear from the beginning that it is intuitive to think of activity eventualities as having no internal structure: an undifferentiated process where the whole event has a temporal extent that simply begins and ends when it does. However, this conceptualization makes it challenging to represent agency in activities, since the notion of agent as "initiator" or "cause" suggests a chain of temporally individuated subevents, only the first of which is due to the agent's action. This seems fundamentally incompatible with the temporal configuration of an activity eventuality, in which the agent must continue to act throughout.

If we were to treat activities as simply super-fine-grained semelfactives, as we mentioned above in section 3, we might capture the intuition that the agent must continue to act in order for the activity to continue. However, this technical solution runs counter to the intuitive introspective percept of an activity predicate as characterizing an undifferentiated single event that lasts as long as it lasts. The DO and PROCESS operators were posited exactly to model this aspect of activity predicate meaning. However, with our more expansive view of causation, which allows us to model entrainment, we now have no need for such bespoke verbal operators.

Other activity and semelfactive verbs, particularly those that involve physical contact *(hit, push, nudge, pat,* etc.), are treated in the same way in this system. So, for instance, just as dancing is the (entrained) creation of dance, pushing a cart is the entrained creation of a push of the cart.[38] Such transitive activity and semelfactive verbs have objects that do not participate in a homomorphism/measuring out. Following Ramchand (2008), we can call these objects "rhemes"; Levin et al. (1999) calls the verbs which select such objects 'non-core transitive' verbs. Any theory comparing these objects to incremental themes has to find a way to insulate such objects so that they do not provide

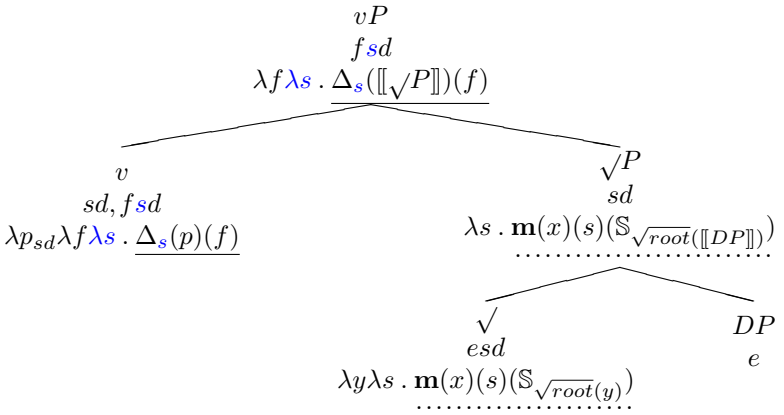
[37] This is also the structure we propose for intransitive uses of incremental theme verbs (e.g. *Mary ate/read*), even for verbs of consumption, which we treated above as involving negative slopes. In intransitive cases, however, we expect the root to be in the low position, since it is necessary for v to have a measure function to apply to. Hence, in Mary *ate*, the root must be providing a scale, not a slope. Any understood theme must be coming from the lexical-conceptual knowledge of the nature the force-kind denoted by 'eat'.

[38] This suggests that Levinson's (2010) "pseudoresultatives", formed from 'Root Creation' verbs (Irwin and Kastner, 2020), such as *braid the hair tight*, which involve the creation of an entity named by the verb root, also fit into this class and should be treated analogously. The pseudoresultative modifier modifies the incorporated N, *braid*; we speculate that *push the cart hard* would have a similar analysis.

extent scales that measure out. In our theory, this issue is particularly acute, as we are proposing that there is always a scale in verbal meaning, so we must be careful to keep the rheme object away from the scale. In our system, this means that the composition that occurs between the root and the rheme occurs in such a way as to jointly provide the scale in the universal measure function.

To achieve this for these non-core transitive cases, we propose that the verbal root composes directly with its argument, following Cuervo's 2014 discussion of the argument structure of non-core transitive verbs (see also the structure proposed for *push* in Harley (2005). In our system, this means that the rheme is part of the material that characterizes the scale, as in (48):

(48) Non-core transitive/Rhemic structure



The scale that $\mathbb{S}_{\sqrt{push}([\![\text{the cart}]\!])}$ names is a non-quantized extent scale of how much there is a pushing of the cart; so, exactly analogous to what we propose for $\mathbb{S}_{\sqrt{dance}}$.

6 Verbs of maintaining

Recall that a major advantage of reifying inputs of energy in verbal predicates is the ease of accounting for verbs of maintaining such as *stay, keep, endure, preserve,* and *maintain*. The idea pursued in Copley and Harley (2015) is that verbs of maintaining involve a force function whose input s and output $f(s)$ are both described by the complement of v. That is, the force is one which makes it the case that the truth value of that predicate does not change on the way from s to $f(s)$. This calls for a treatment in terms of a zero slope, a natural extension of the tool we developed above to capture the difference between creation and consumption predicates. As before, we locate the slope in the root. These verbs, then, pick out all the forces that have a zero impelled

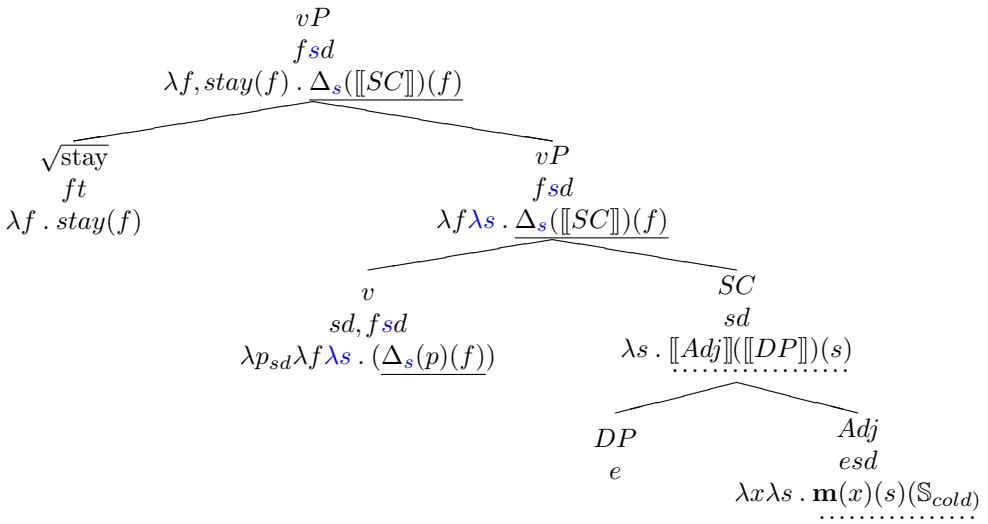
difference on some property.[39]

We note, additionally, that the scale for predicates of maintaining can have a location dimension (e.g., *stay home*), or an adjectival dimension (e.g., *keep cold*), as well as an extent dimension (e.g., *preserve, endure*).

The root $\sqrt{stay}$ contributes a slope and takes a small clause as its argument, as can be seen from the fact that (49a) is unacceptable but (49b) and (49c) are acceptable. (49a) provides no predicate on which to build a small clause, while (49b), (49c), and (49d) each provide a predicate for the small clause.

(49) a. *The cup stayed.
b. The cup stayed whole.
c. We stayed at home.
d. The ice stayed cold.

(50) *stay cold*



We have a kind of complementary set of verbs of maintaining for expressing dynamic persistence of an entity, namely *endure, preserve*. This can be seen from the distribution and interpretation of co-occurring adjectival and prepositional phrases; with *stay*, the phrases are required secondary predicates (in (49) above), while with *endure*, they are adjuncts. We see this first from the fact that (51a), unlike (49)a, is felicitous on its own; no other material is required in the complement of *endure*.

[39] Recall that, unlike Kennedy and Levin's 2008 measure of change function, our measure of impelled difference function is defined even when its value is zero. Verbs of maintaining would thus not be explained using their function (though of course verbs of maintaining were not the focus of their investigation at all). Their function could be changed to be defined at zero, but because this fact features in their account of entraining change of state predicates, they would then likely have to change their analysis of entraining cases.

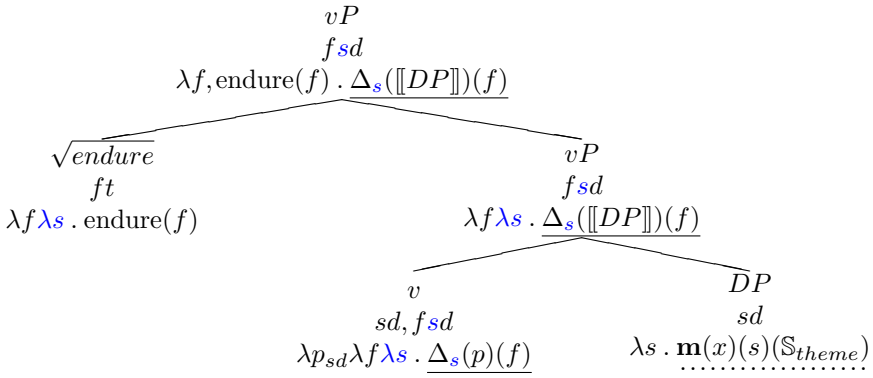
(51) a. The cup endured.
b. We endured (at home). only adjunct reading
c. The cup endured (whole). only adjunct reading

The adjunct status of, e.g. *at home* in (51b) can also be seen in the contrast between (52a) and (52b); as expected, the adjunct PP's word order is more flexible than that of the secondary predicate PP required by *stay*.

(52) a. ??At home, we stayed.
b. At home, we endured.

We propose to treat *endure* and *preserve* as the zero-slope counterparts to verbs of creation and consumption: The theme occurs as the complement of v and *endure* specifies that the slope between s and $f(s) = 0$. The dimension of the scale is provided by the theme, as in the verbs of creation and consumption, and is thus D_{extent}.

(53)



This account of verbs of maintaining on its own derives a presupposition that Copley and Harley (2015) had to stipulate, namely that verbs of maintaining apparently *presuppose* that something exists in, or a predicate holds of, s; in contrast to *asserting* the same of $f(s)$). Since here we treat verbs of maintaining as having zero slope, we can see that the same is true of incremental theme predicates of creation and consumption, as our theory would predict. For example, with *eat the soup*, the soup is presupposed to have a certain extent before the eating; with *paint the picture*, the picture is presupposed not to exist before the painting creates it. That is, we accommodate the existence of a degree to which the entity is there in s and another (in this case, equivalent) degree to which the entity is there in $f(s)$. The picture emerging is that initial conditions (things predicated of s) get presupposed, while final conditions (things predicated of $f(s)$) get asserted. This is a more satisfactory characterization of these presuppositions than simply stipulating them.

7 Ditransitive structures

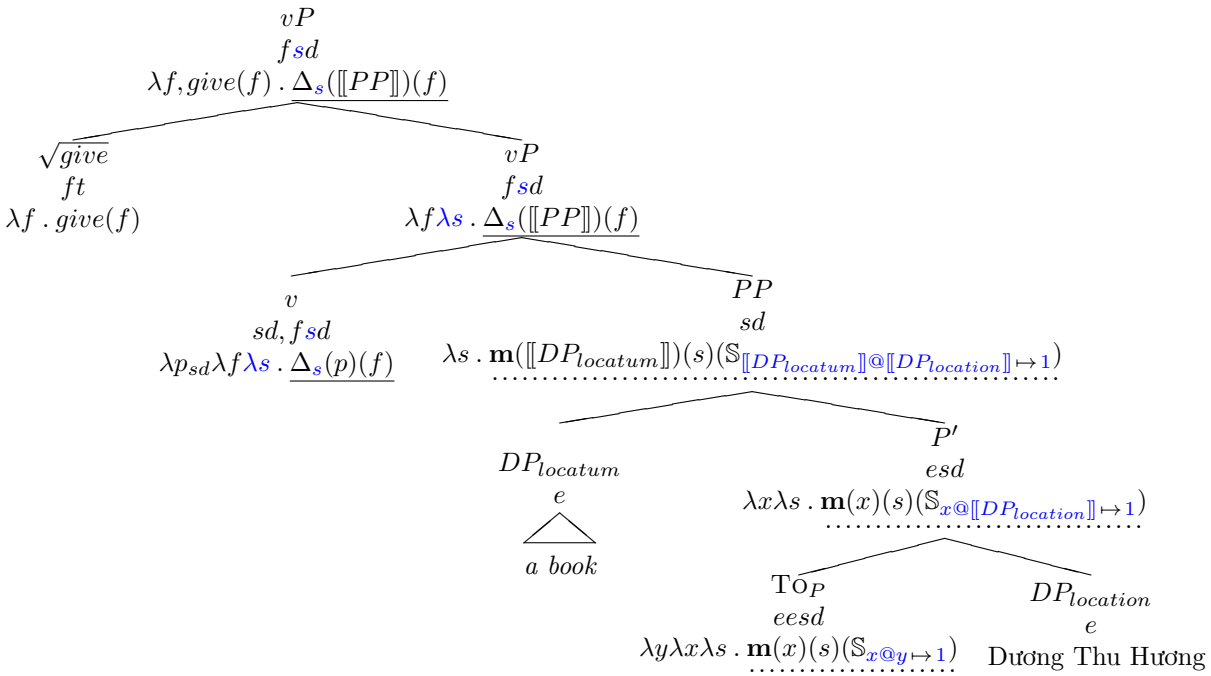
Ditransitives are already understood in modern syntactic theories as causation structures, involving a locatum (the figure, which moves) that is caused to come to be at a location (the ground). This is typically represented with a vP-shell structure, with the v as usual introducing the causing event and the change of state encoded as a relation between the locatum and the location; nothing significant about this general picture will change in our treatment here. In this section we will use x to represent the locatum and y to represent the location.

We will first consider the *to*-dative construction such as *give a book to Mary*, where the location is the object of a preposition *to*, our denotation of which in (30) is repeated below in (54):

(54) $[\![to]\!] = \lambda y \lambda x \lambda s \,.\, \mathbf{m}(x)(s)(\mathbb{S}_{x@y \mapsto 1})$

Our proposed structure for *to*-datives is given in (55) below. It captures Bruening's (2010) insight that in the *to*-dative structure the verb selects directly for the *to*-PP, with no need for an applicative projection or other mediating functional material.

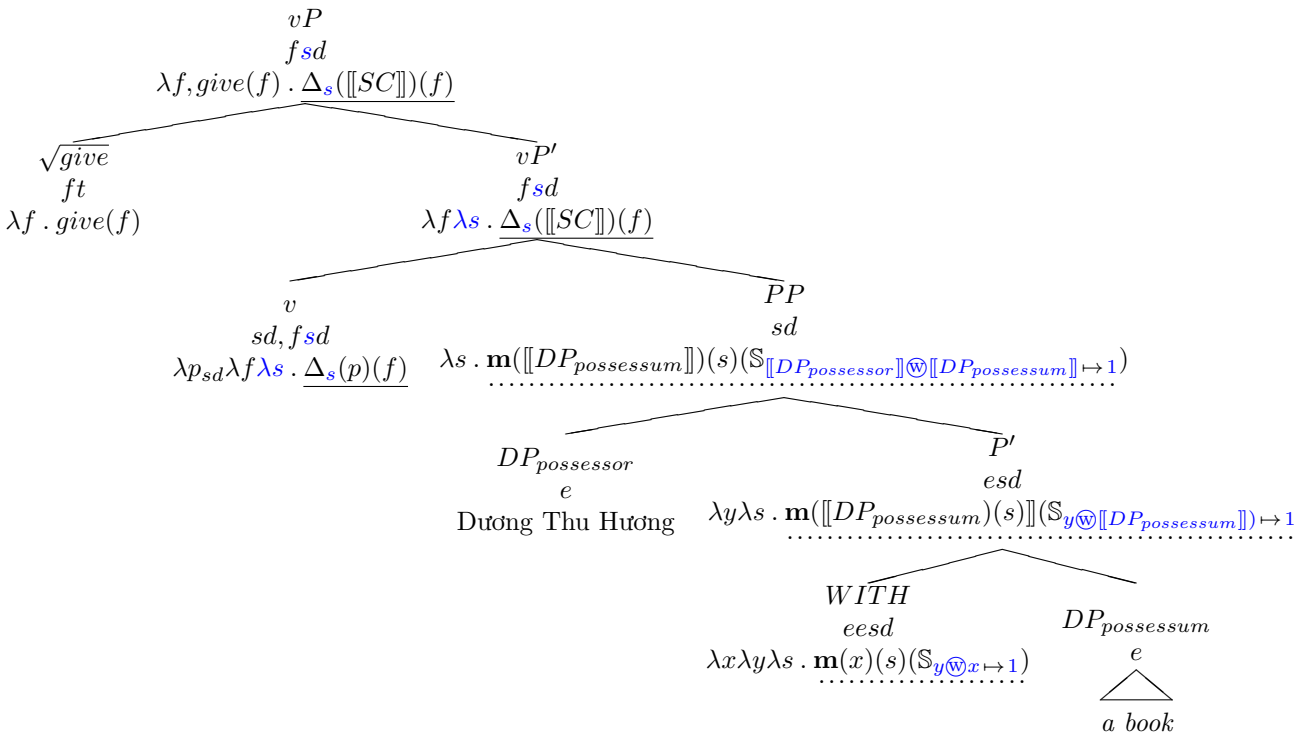
(55) give a book to Dương Thu Hương (*to*-dative ditransitive structure)



Certain ditransitive verbs also participate in the dative alternation (see Levin, 1993, p. 45-47 for a comprehensive list of such verbs and early citations). Compared to the *to*-dative structure above in (55), the positions of the locatum x and the location y are reversed, there is no overt preposition and there is a slightly different semantic quality, requiring a possession interpretation even with verbs like *send* that do not require it in the *to*-dative. Most approaches posit a distinct predicate relating x and y, introducing the possession reading; theories vary as to the identity of this predicate ('low' applicative, P_{HAVE}), but it is the crux of the double object construction. We adopt a version of the P_{HAVE} proposal, naming our preposition WITH, and including in its denotation a possession relation "Ⓦ". Like the @ relation, this relation is crucially categorial in character, involving a two-point scale where being without x corresponds to 0 and being with x corresponds to 1 (and see, e.g. Beavers and Koontz-Garboden, 2020).

(56) a. $\textsc{With} = \lambda x \lambda y \lambda s \,.\, \underline{\mathbf{m}(y)(s)(\mathbb{S}_{y \text{Ⓦ} x \mapsto 1})}$

(57) give Dương Thu Hương a book (double object structure)



The motivation for using a possession predicate in double object structures derives from the fact that the *to*-dative and double object constructions are famously distinct in their semantic details. Recall the old observation that *to*-

dative structures are incompatible with inanimate subjects, while double object structures permit them (Green, 1974; Oehrle, 1976). That is, *to*-dative structures require an agent, as shown in (58), but double object structures permit a causer as well, as shown in (59).

(58) a. The student gave a book to Dương Thu Hương.
b. #The Vietnam War gave a book to Dương Thu Hương.

(59) a. The student gave Dương Thu Hương a book.
b. The Vietnam War gave Dương Thu Hương a book.

This contrast is represented in the framework here as resulting from the interaction of the root denotation with the different denotations of the predicates below it in either case. In the case of the *to*-dative, the conceptual giving force has to impel the locatum through physical space to the recipient. The student, as a concrete, force-generating entity (Folli and Harley, 2008; Copley et al., 2015), can be the source of such an input of energy but the Vietnam War, as an abstract entity, can't. In contrast, in the double object construction, the categorical scale with an abstract result introduced by WITH is consistent with abstract sources.

8 Conclusion

Our goal was to "tame the verbal Hydra" by obviating the need for multiple v heads. In service of this goal, we hypothesized a unified denotation for dynamic v based on a framework that includes both degree arguments and force functions. In this denotation, a force (an input of energy) impels a change (perhaps zero) along a degree scale. Our unified denotation embodies our hypothesis that there is a basic meaning of English dynamic verbs, and exemplifies a working theory of the syntax-semantics interface which turns largely on type theory and the characterization of scales.

What are the possible structures? The possible structures we propose are the following. Boxed items are those that can be realized by a root, and bolded items are those that have the measure function in their semantics. Note that verbs (roots) of maintaining occur in the structures in (60a), (60b), and (60d).

(60) Possible structures

a. Change-of-state: $[_{vP}\, v\, [_{SC}$ theme $\boxed{\textbf{predicate}}]]$

b. Incremental theme: $[_{vP}\, \boxed{\text{manner/slope}}\, [_{vP}\, v\, [_{DP}\, \textbf{theme}]]$

c. Activity/semelfactive: $[_{vP}\, v\, [_{\sqrt{P}}\, \boxed{\textbf{theme}}\, ([_{DP}\, \text{rheme}])]]$

d. Change-of-location/possession:
$[_{vP}\, \boxed{\text{manner/slope}}\, [_{vP}\, v\, [_{PP}\, \boxed{\text{locatum/location}}\, [_{P'}\, \boldsymbol{P}\, \boxed{\text{location/locatum}}]]]]$

A note about manner: Any one root is only realized in one slot in any given structure. Manner is only realized by roots. So, if the verbal root is in a non-manner slot, manner is not realized. This captures the Manner-Result Complementarity pattern first modelled by Levin and Hovav (1991, 2006), where either manner or result is lexically conveyed but not both (*pace* Beavers and Koontz-Garboden (2020)).

In the end, what *would* it take to tame the verbal Hydra? The most challenging, but also we think the most productive, moves of our proposal came in the first half of the paper. We asked the reader to entertain two dramatic and fundamental reimaginings of the ontology of the verb phrase.

The first such move (and see also Copley and Harley (2015)) was the idea that Ramchand's "causal glue" of the verb phrase is *itself* the Davidsonian argument in dynamic predicates. With this idea in place, we can represent as causal not only launching (effect after cause) but also entrainment (effect during cause). This in turn opened up the door to the observation that some work on degree semantics in the verb phrase, and especially the proposal in Kennedy and Levin (2008), could be seen as recapitulating the launching/entrainment distinction. This point led to the proposal that some of that semantics needs to be relocated to the verbal head.

In a way, it's not surprising that these first moves were both the most challenging and the most productive, given that they ask for a shift in one's ontological commitments. Ontological commitments are difficult to change, but if the change is appropriate, it can yield important insights that were not accessible in the old ontology. In this case, by shifting our representation of causation to one that accounts for entrainment, and by recognizing that degree semantics relates to (a)telicity via the notion of causation, we provided a simplified interaction between grammatical and conceptual representations of causation. We hope that the resulting consequences have been worthwhile.

Compared to those ontological moves, the other things we needed in order to tame the verbal Hydra were less momentous. We needed roots and other linguistic objects to characterize scales; crucially for us, quantized scales had to have only one ordered pair in their ordering relation. To adjoin roots in the manner/slope position above our single v head, we generalized Predicate Modification to a new rule of composition, Predicate Restriction. And we delegated two general properties of verb meanings to the lexicon, proposing that "slopes" (increase/decrease/maintain) and "metonymic extents" (for *mow the lawn* e.g.) are pertinent to roots only.

Since all of these seem plausible to us, we feel we have provided proof of concept that the verbal Hydra can be tamed, with a formal system no more complicated than the one we have proposed here.

9 Compliance with ethical standards

The authors declare that they have no conflicts of interest regarding this research.

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