What would it take to tame the verbal hydra?

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Abstract  Prominent theories of the syntax-semantics interface in the verb phrase propose multiple verbal heads, either in parallel (Folli & Harley 2005a,b), or in series (Ramchand 2008, 2017). In either case, the need for syntactic heads to select appropriate lexical roots requires that a considerable amount of information is duplicated between the lexicon and the syntax. In this paper we investigate some consequences of proposing a single unified verbal head for dynamic predicates, with the aim of reducing the selection problem to ordinary type-driven semantic composition. To construct the denotation of the unified verbal head, we adopt two recent ontological innovations to the theory of event structure: the use of degree arguments to represent change (e.g. Hay et al. 1999, Kennedy & McNally 1999, Kennedy & Levin 2008, Kennedy 2012) and the use of force arguments to represent energy (Copley & Harley 2015). We explore several departures from strict typological composition (type shifts, rules of composition) that are needed for this account to work for basic dynamic verbal types.

Keywords: verb phrase, syntax-semantics interface, telicity, change, degree arguments, force arguments

1 Introduction

The syntax-semantics interface in the verb phrase has been a topic of intense research for several decades, in large part because verb phrases offer a rich proliferation of phenomena which have both semantic and syntactic reflexes. Some of these are exemplified in (1):

(1) Splitting
   a. telic vs. atelic vs. variable telicity
      climb the mountain vs. dance vs. eat apples/the apple
   b. different 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

* We are indebted to Daniel Altshuler, Hana Filip, and the audience at Düsseldorf in 2015 for providing us with the input of energy to start redeeming this promissory note from our 2015 paper. We’re grateful too for their helpful comments, as well as those from audiences in Toronto (Dog Days 2014), Nijmegen (Formal Semantics Meets Cognitive Semantics Workshop 2015) Paris (the project DelimitEvent of the CNRS Fédération Typologie et Universaux Linguistiques, 2015), and Nantes (2018).
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 is only the major factors that arise in English; other issues, including those having to do with the onset of the event, arise in other languages (Marín & McNally 2011, Choi 2015).

How one accounts for this proliferation depends 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 & Rappaport Hovav (1995) and those that privilege structural reflexes of these phenomena (Borer 2005). A hybrid way to account for the proliferation is to use multiple verbal heads, either in parallel (i.e., in complementary distribution) (Folli & Harley 2005a,b), or in series, (i.e in an extended projection) (Ramchand 2008, 2017), where verbs instantiate different heads with unique semantic content and related structural properties.

While all of the theories above pay close attention to the shape of the syntax-semantics interface, there is still room for improvement. For one, multi-headed theories need to duplicate a certain amount of information in the lexicon and the syntax to ensure that the right syntactic heads are associated with the right roots. Perhaps the slenderest syntax-semantics interface would depend on a single mechanism, e.g., either features or semantic types. We could also wish that the proliferation of null syntactic heads could be constrained in a principled way.

With this wishlist in mind, the question we raise here is the following: What would it take to reduce the many-headed hydra of the verb phrase down to a single v head? Our answer begins by “exploding” the Davidsonian event argument.

Davidsonian event arguments (Davidson 1967) have been widely adopted in formal approaches to the semantics of the verb phrase. In previous work (Copley & Harley 2015), we 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, we argued, the arguments of dynamic verbal predicates correspond more closely to the idea of a *force*—an input of energy. We argued this on the basis that although the commonsense idea of an event is a change of some kind, certain Davidsonian arguments do not require change, notably the Davidsonian argument of verbs of maintaining such as *keep* and *stay*. Moreover, this approach aligns the treatment of atelic dynamic predicates (activities and semelfactives) with that of telic predicates.

If we are correct in this move, then change is irrelevant to the individuation of Davidsonian arguments of dynamic1 verbal predicates. However, irrelevant though it might be to the Davidsonian argument, change is clearly implicated somehow in a host of predicate types; in particular, change along degree scales (Hay et al. 1999, Kennedy & McNally 1999, Kennedy & Levin 2008). Still, if degrees represent change, it would be overkill for the Davidsonian arguments of verbs of maintaining such as *keep* and *stay*. Moreover, this approach aligns the treatment of atelic dynamic predicates (activities and semelfactives) with that of telic predicates.

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1 We use the word *dynamic* in the sense of ‘energetic’, though it is also often used in the sense of ‘involving change’; see Copley (2018). For us it is the opposite of ‘stative’: as dynamic predicates refer to an input of energy and stative predicates refer to situations without energy. We will have nothing to say about any stative flavors of v here.
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argument to represent change as well. Thus what seems to be called for is a picture where energy is reified by force arguments and change is reified by degree arguments.

In this paper we do exactly this. We find that the advantages of both forces and degrees are retained, allowing us to account for verbs of maintaining while permitting a natural degree-based account of the classical homomorphisms (Tenny 1987, 1994, Verkuyl 1993, Krifka 1989, 1992, 1998). Moreover, the whole will prove to be more than the sum of its parts. This approach using forces and degrees seems to have the potential to cover all dynamic predicates, not just those that involve variable telicity. We hypothesize that all dynamic verbs have a structure in which a force causes a (possibly zero) difference in the degree to which a predicate holds. This meaning would be contributed by the verbalizing head v, so that the multiple verbal heads, at least for dynamic verbs, could be reduced to one.

On the lumping-splitting continuum, our aim here is obviously to lump. Splitters can take heart, however. While our goal is to arrive at a unified compositional semantics that distills what is common to dynamic verbal predicates, the fact that dynamic verbal meanings are so diverse means that the meaning of the v head is not the complete picture. Thus, along the way we will note where lexical roots must play a role to elaborate the meaning.

For example, for telicity, we argue that the difference in root meanings that allow telicity or atelicity is due to the temporal relationship between cause and effect, which (following Filip (2008) among others) is not represented in the logical form in English. We will argue that root meanings allow 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. The contrast between homomorphic and non-homomorphic objects will be argued to involve differences in compositional structure, depending on the type of the root. The reason, then, that homomorphisms show up in some, but not all, verbal predicate meanings will be because quantization is only one of the many kinds of scales invoked in verbal causal relations (see, e.g. Hay et al. 1999, Kardos 2012, Kennedy 2012: for scalar treatments of quantization). The difference between manner and result verbs as well will be due to type, which boils down to two 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. Finally, verbs of maintaining will be encoded directly in the meaning of the root (contra what we said in Copley & Harley (2015)).

In this way, while the dynamic verbalizing head v contributes the similarity among dynamic verbal meanings, roots, and the structures that their properties give rise to via type theory, are expected to contribute the diversity. We will not be able to give a full story for every kind of root, but in pointing out some of the issues, and in attempting to stake out a dividing line between the compositional and the lexical, we hope to provide the inspiration for further investigation.

Finally, we note that in addition to unifying the denotation of v, we hope to be able to limit the syntax-semantics interface—i.e., the information that is shared between the lexicon and the compositional system—the evaluation function, along with compositional rules and type theory. If realized, this would represent an advance in simplification not only over multiple-head theories, but also over frameworks that require multiple heads to be listed in
the lexicon; it would be a slimmer interface than anything else on the market (including Borer (2005), who needs both features and semantic types).

We move now to present background on entrainment and launching, and how they reflect the degree-based analysis of telicity as well as the force-theoretic framework of Copley & Harley (2015) (FTF1). We then add degrees to FTF1 to make FTF2, and give the unified analysis of v. Subsequently we show what we need to do to the theory of composition to help this framework deal with various predicates: changes-of-state, activities, verbs of consumption and creation, other incremental theme verbs, and verbs of maintaining. We find that one or two type shifts are useful, as well as a rethinking of Predicate Modification, and an assumption that situations are thin.

2 Background

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. More recently this fact has been modeled in artificial intelligence-inspired treatments of events (Fernando 2008, van Lambalgen & Hamm 2008). We use Michotte’s terms, translated from French, for the two relationships, given in (2):

\[(2) \begin{align*} 
\text{a. } \text{launching: the cause precedes the effect} \\
\text{b. } \text{entrainment: the cause and the effect happen at the same time}
\end{align*}\]

To illustrate these two relationships, we can 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 simply push the cup (an atelic predicate), the result that is described is the cup’s moving; 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, they need not be states.

Entrainment, however, poses a serious problem for Davidsonian events as typically understood. One way this can be seen is from the fact that work on Davidsonian event semantics at the interface with syntax has not paid any explicit attention to entraining causation. There is tremendous amount of work on launching causation, corresponding to a subevent analysis of telic eventualities: Pustejovsky (1995), Dowty (1979), Rothstein (2000), Higginbotham (2000), Ramchand (2008), among others.

In all of these, there is a causal relation between at least two temporally sequential event-like elements. However, activities (dynamic atelic eventualities) such as sing or run are typically treated as simplex events; they are not treated as having results at all.

There are two excellent reasons why activities were not generally treated as having results in such frameworks. One reason is conceptual: Davidsonian events are meant to be individuated on the basis of their participants and their spatiotemporal location. In activities there is one set of participants at a single time and place, so there is no reason to say that there are two events there. Hence, the intuition that activities involve entrainment causation cannot really be cashed in as one Davidsonian event causing another. Another reason why
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no one ever treated activities this way is empirical: activities fail tests that are supposed to
distinguish result events from causing events, such as the test for restituitive again.

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

Treating atelic dynamic predicates as 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 something of a non-starter for
result event arguments. We will not address the again problem in this (version of this) paper,
instead concentrating on the event individuation problem.

While Davidsonian event causation for entrainment was stuck on the launch pad as it
were, there was a separate development in formal semantics that 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 extending it to incremental theme verbs (Hay et al. 1999, Kennedy &

The idea behind the degree approach is that the predicate makes reference to a scale,
and telicity corresponds to the case when satisfaction of the predicate occurs on reaching
the maximum endpoint of the scale. Atelicity, on the other hand, corresponds to the case
when there is no endpoint specified, and the predicate is satisfied by any minimal amount
of change that occurs. With any given verbal predicate, we thus need to check whether the
result begins as soon as the scalar change begins, or whether the result obtains only at the
end of the scalar change, 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 (launching). On the other hand, if you eat soup, from the very
beginning you achieve the result of (non-quantized) soup being eaten (entrainment).

This kind of argumentation is familiar. Our contribution here is to relate this picture
to the temporal structure of causation. The specified maximum and unspecified maximum
cases reflect the two different temporal relationships between cause and result, launching and
entrainment respectively. In cases where the maximum on the scale is specified, a force—an
input of energy—causes the current degree to advance along a scale, but the result only
occurs in time at the point 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 change 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. The addition of forces thus deepens our understanding of the connection between
reaching a value on a scale and (a)telicity.

This move suggests that a simplification of the semantics of dynamic verbal meanings
is possible. They will all involve an input of energy that changes a degree on a scale. In
the meantime, the use of force arguments still has the advantages discussed in Copley &
Harley (2015). In particular, there is no conceptual problem with an input of energy that
simultaneously provokes a result, as in atelic dynamic predicates.
2.2 A force-theoretic framework (Copley & Harley 2015, FTF1)

We adopt the force-theoretic framework from Copley & Harley (2015) in which there is a type difference distinguishing forces and situations. Situations are something like those in situation semantics (Barwise & Perry 1983). Informally, a situation includes individuals and their property attributions. We adopt Barwise and Perry’s distinction between situations in the world and situations in language. Likewise, a force in the world (an input of energy) is represented in language by a function from an initial situation to a ceteris paribus final situation. The point that forces in the world and forces in language are not identical is worth underlining, as 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 predicates that represent them in language, e.g., a property such as color is not a function either (Bealer 1989).

This means we have a dual ontology: on the one hand, a linguistic ontology with functions and variables, and on the other, a conceptual ontology that has in it properties such as color, and also includes inputs of energy (conceptual forces), and conceptual situations. This dual ontology is not new either: the two ontologies correspond to the domain and range, respectively, of the evaluation function $J$. It’s just that the difference between the conceptual and linguistic side is typically not at issue, and sometimes not so clearly obvious, to linguists at least. With forces it’s more clear that a conceptual force is different from a linguistic force function, so it’s worthwhile to make explicit the distinction between the two ontologies.\footnote{We did not always take the dual ontology idea all the way to its logical conclusions in Copley & Harley (2015); we will not even do so in this paper. In particular, roots, being lexical, should take conceptual variables as arguments, since the lexicon resides at the conceptual level. We will not make this move in this paper, to avoid introducing more complexity. Still, the dual ontology is relevant to understanding how force functions work, so we include the discussion here.}

So, a linguistic situation $s$ is mapped via the evaluation function to its corresponding conceptual situation $\sigma$, i.e., $[s] = \sigma$. A force function $f$ is mapped, via the evaluation function, to its corresponding conceptual force $\varphi$, i.e., $[f] = \varphi$. Force functions are rather boring functions; they have a single situation $s$ in their domain and a single situation $s'$ in their range. Force functions are hence type $\langle ss \rangle$, which we will abbreviate as type $f$.

The situation in the domain, the “initial situation”, corresponds to the conceptual situation $\sigma$ from which the conceptual force $\varphi$ arises. A conceptual force $\varphi$ is a net force of a conceptual situation $\sigma$ just in case $\varphi$ arises from all the individuals and property attributions (or tropes, if you prefer) in $\sigma$. So the relevant relations among $f, s, \varphi,$ and $\sigma$ are as in (4). There’s one relation missing: there is no direct relationship between $f$ and $s$. But through the evaluation function which maps $f$ and $s$ to $\varphi$ and $\sigma$ respectively, $f$ and $s$ stand in for $\varphi$ and $\sigma$ which do have a direct relationship, so it will be possible to define a relationship between $f$ and $s$.\footnote{We did not always take the dual ontology idea all the way to its logical conclusions in Copley & Harley (2015); we will not even do so in this paper. In particular, roots, being lexical, should take conceptual variables as arguments, since the lexicon resides at the conceptual level. We will not make this move in this paper, to avoid introducing more complexity. Still, the dual ontology is relevant to understanding how force functions work, so we include the discussion here.}
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(4)

<table>
<thead>
<tr>
<th>language</th>
<th>language-cognition interface</th>
<th>cognition</th>
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<tbody>
<tr>
<td>( f )</td>
<td>— related by evaluation function to —</td>
<td>( \varphi )</td>
</tr>
<tr>
<td></td>
<td>is the net force of ( \text{arises from all the individuals and property attributions in} )</td>
<td></td>
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\( S \) | — related by evaluation function to — | \( \sigma \) |

We still need to explain the “final situation” \( s' \) (note that it is the causally final situation, i.e., the result, not the temporally final situation; this is the key point that allows us to model entrainment as well as launching). The function \( f \), when it takes the initial situation \( s \) as its argument, yields \( s' \): \( f(s) = s' \). The interpretation of this on the conceptual level is as follows. The (linguistic) final situation \( s' \) corresponds to the conceptual situation \( \sigma' \) that occurs in the case where no force arising (in whole or in part) from outside \( \sigma \) interferes. The final situation (on either the conceptual or the linguistic level) is thus merely a \textit{ceteris paribus} final situation, as it only occurs if “all else is equal”, i.e., if nothing external to \( \sigma \) intervenes.

Now we define a causal chain based on these constructs. We define two linked sequences, one of situations and one of force functions, as in (5), inductively as in (6):

(5)  
a. \( \ldots s_{-1}, s_0, s_1 \ldots \)  
b. \( \ldots f_{-1}, f_0, f_1 \ldots \)  

(6)  
a. Let \( f = \text{net}(s) \) iff \( [f] \text{ is the net force of } [s] \)  
b. \( f_n = \text{net}(s_n) \)  
c. \( s_{n+1} = f(s_n) \)  

The function \( \text{net} \) provides the missing link between \( f \) and \( s \), via the existing link between \( [f] \) and \( [s] \).

It will also be useful to define functions that return the initial or final situation given any particular force:

(7)  
a. \( \text{init}(f_n) = s_n \)  
b. \( \text{fin}(f_n) = s_{n+1} \)  

Finally, a few words about how we will be using all this to represent basic eventuality types and agency. Like some but not all event-theoretic frameworks, our framework provides a type difference between stative and dynamic predicates. Stative predicates such as \textit{be in the room},
know French are treated as predicates of situations, type \( \langle st \rangle \). Dynamic predicates such as eat and stay are predicates of forces, type \( \langle ft \rangle \), aka \( \langle ss, t \rangle \). Active Voice, when present, introduces the Agent/Causer as the (main) SOURCE of the energy constituting the force.

3 FTF2: Adding degrees to FTF1

3.1 Adding degrees

Using this framework, we now will show how some basic verbal types can be understood in terms of forces and degrees, and see what the compositional theory would have to look like to support a single unified verbal head for these verbal types. In earlier work (Copley & Harley 2015), building off Dowty’s (1979) BECOME which ensured that \( p(t_1) \& p(t_2) \), we proposed interpretations for several “flavors” of \( v \) (Folli & Harley 2004), including the at-issue meaning associated with \( v_{\text{become}} \) as in (8):

\[
(8) \quad v_{\text{become}} : \lambda p \lambda f . p(\text{init}(f)) \& p(\text{fin}(f))
\]

We proposed other flavors as well. We noted that existing work on scales would need to be integrated into the proposed semantics of change of state verbs, and that the various denotations for the different \( v \) heads we proposed all have intuitively similar content, but we postponed a full exploration of how that intuition might be cashed out in a unified analysis of \( v \).

Now, as we integrate degree scales into the force-theoretic framework, we can hypothesize a core meaning for \( v \), at least for dynamic verbs in English and languages like English. Recall that given a force \( f \), we can name its initial and final situations \( \text{init}(f) \) and \( \text{fin}(f) \) respectively. That is, \( \text{init}(f) \) is the situation from which the energy arises, and \( \text{fin}(f) \) is the result provoked by that energy. Suppose we are interested in a measure function \( p \) (where \( p \in D_{\langle sd \rangle} \) ) that holds to one degree in \( \text{init}(f) \) and to another degree in \( \text{fin}(f) \). We take degrees and scales to be as in Kennedy & McNally (2005): triples \( \langle S, R, \delta \rangle \) where \( S \) is an (open or closed) set of degrees, \( R \) is an ordering (increasing for ‘positive’ adjectives like warm, decreasing for ‘negative’ adjectives like cool, and \( \delta \) is the dimension of difference).

Now, to integrate degree-talk with force-talk, we define \( \Delta(p)(f) \) as the span of the degree scale from the degree to which \( p \) holds in \( \text{init}(f) \) to the degree to which \( p \) holds in \( \text{fin}(f) \).

We also want to define degree-points and degree-intervals, analogous to temporal instants and temporal intervals. As is often done for the temporal case, we’ll use the same type for these (though a different type could be used without problems). We’ll use the notation \([d_1, d_2]\) to notate an interval spanning all the degree-points between \( d_1 \) and \( d_2 \) inclusive. For ease of reading, descriptions of degree-points will be written with a dotted underline, and descriptions of degree-intervals will be written with a solid underline. These underlines are just a convention for ease of reading and are not a necessary part of the equations.

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3 It will become clear in section 3.3 why we define the degree of change in exactly this way; it is based on Kennedy & Levin (2008) but is a bit different.
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Now we can define what we will call the “measure of impelled change,” which forms the heart of the denotation of unified dynamic $v$. This definition is for convenience only so that we can more easily follow the meaning of $v$ going up the tree by following the deltas.

(9) Measure of impelled change:
$$\Delta(p_{sd})(f) = [p(init(f)), p(fin(f))]$$

The measure of impelled change measures the degree-interval between $p(init(f))$ and $p(fin(f))$ inclusive. Then the hypothesized unified meaning of the $v$ head for dynamic verbs is to give a measure of impelled change as in (10). That is, $v$ takes a measure function $p$ and a force and returns the delta measuring the change in $p$ as a result of $f$.

(10) Unified dynamic $v$:
$$[v] = \lambda p_{sd} \lambda f . \Delta(p)(f)$$

Except for the use of forces rather than events, this unified meaning reflects the verb meaning from the degree literature, in that participation in an event (here, a force) causes the change of a degree on a scale. This proposal is also reminiscent of Koenig & Chief’s (2008) account of non-culminating accomplishments, though here we characterize not only the caused result $fin(f)$, but also the causing situation $init(f)$, with their corresponding values on a degree scale.

A key part of the analysis, which we will keep in mind as we proceed, is that we apply a criterion to figure out when $s_1$ begins: whenever the current degree $d_{current}$ equals the degree $d_1$ specified in the predicate, $s_1$ begins. If $s_1$ begins as the force in $s_0$ is being applied—which will occur whenever the relevant scale is an open scale—we have entrainment and atelicity. If, on the other hand, $s_1$ begins as $s_0$ ends—which will occur whenever the relevant scale is a closed scale—we have launching and telicity. The temporal relationship, whether launching or entrainment, is not represented in the denotation, however.

We will now show how this proposal applies to a number of different kinds of predicates, and see what the compositional consequences are.

### 3.2 Change-of-state verbs

First we will show how change-of-state predicates are accounted for. There will be no surprises here; we closely follow Kennedy & Levin (2008). Recall that telicity emerges when a maximum is specified, either contextually or in the phrase structure, which yields launching, and atelicity emerges when a minimum amount of change is used, yielding entrainment. We assume that adjectives refer to simple measure functions such as in in (11), where $m$ corresponds to any given scalar adjective, e.g. flat, open, hot, etc:

(11) $m(y)(s) = \text{the degree } d \text{ such that } y \text{ has the property } m \text{ in } s \text{ to the extent } d$

The meanings of such adjectives participate in degree achievements, which are paradigm cases of change-of-state predicates. Such adjectives can be associated either with a closed scale, i.e. one with an inherent endpoint (like flat), or an open scale, with no endpoint (like hot).
When such adjectives form the basis for change-of-state-denoting verbal structures, they compose structurally as in (12), regardless of whether the adjective is associated with an open or closed scale, and regardless of whether the vP is telic or atelic.

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

\[
\text{vP} \\
(\langle fd \rangle) \\
\lambda f . \Delta([SC])(f) \\
\text{v} \\
\langle sd, fd \rangle \\
\lambda p_{(sd)} \lambda f . \Delta(p)(f) \\
\text{SC} \\
\langle sd \rangle \\
\lambda s . [\sqrt{([DP])(s)}] \\
\text{DP} \\
\langle e, \langle sd \rangle \rangle \\
\lambda y \lambda s . m(y)(s) \\
\text{PPPP} \\
\text{e} \\
\sqrt{\langle e, \langle sd \rangle \rangle} \\
\lambda y \lambda s . m(y)(s)
\]

So, for instance, \textit{v} \textit{heat the soup} gets the following derivation:

(13) \[ [v] ([\text{heat the soup}]) = [v](\lambda y \lambda s . \text{hot}(y)(s) ([\text{the soup}]) (s)) \]

\[
= [v](\lambda y \lambda s . \text{hot}(\text{the soup})(s)) \]

\[
= \lambda p_{(sd)} \lambda f . \Delta(p)(f) (\lambda y \lambda s . \text{hot}(\text{the soup})(s)) \]

\[
= \lambda f . \Delta(\text{hot}(\text{the soup})(s))(f) \]

\[
= \lambda f . \text{id} : [\text{hot}(\text{the soup})(\text{init}(f)), \text{hot}(\text{the soup})(\text{fin}(f))] \]

Assuming without analysis that \([\text{the soup}]\) picks out the appropriate individual, and using the definition of measure functions such as \text{hot} in (11), the entire function then takes a force \(f\) and returns the degree-interval spanning all the degrees between the degree to which the soup is hot in \text{init}(f) and the degree to which the soup is hot in \text{fin}(f) inclusive.

The analysis straightforwardly follows the degree and force accounts already given. According to the degree account, the verb \textit{flatten}, built on a closed-scale adjective such as \textit{flat}, is telic because there is a maximum flatness specified. Adding forces, the criterial \text{fin}(f) situation—defined by maximum flatness—begins after the force has been exerted, thus it is launching and therefore telic.

Open-scale deadjectival verbs are accounted for as well. For the degree account, they are atelic when there is no maximum specified, so any change counts from the beginning. Forces add the idea that the minimum change is criterial for determining when the result situation \text{fin}(f) begins; as soon as there is any change, \text{fin}(f) has begun, hence we are in an entrainment, and atelicity. (A maximum can be specified in other ways, as we will see,
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but when it is not specified the verb itself does not provide one, since an open scale does not provide a maximum.)

3.3 Modifying the measure of impelled change

Degrees are frequently modified explicitly by prepositional phrases such as by- and to-phrases. We capture such facts in the current approach in a way that is very similar to ’s proposal. These modifiers can’t be as low as the (result-predicate-denoting) small clause, because they refer to the measure of impelled change, so they have to adjoin to vP. By picks out the span of a degree-interval (intuitively, the degree-interval’s maximum degree-point minus its minimum degree-point), and to picks out the maximum degree-point of a degree-interval. (This is why we defined the measure of impelled change as returning a degree-interval, so that both the span and the maximum could be recovered from it.)

(14) a. For any degree-interval d, span(d) = the measurement in degrees of the whole of d
b. For any degree-interval d, max(d) = the maximum degree-point of d

The denotation of to is as in (15) below. It takes a degree(-point) d′ and a degree-interval (constructed out of π and f) and returns true if d′ is the final degree-point of that degree-interval.

(15) \[ \text{to} = \lambda d' \lambda f \lambda \max(\pi(f)) \]

(16) heat the soup to 100 degrees

\[ vP \langle ft \rangle \]
\[ \lambda f . \max(\Delta(JSC)(f)) = 100^\circ \]

\[ vP \langle fd \rangle \]
\[ \lambda f . (\Delta(S)(f)) \]
\[ \text{the soup hot} \]

\[ PP \langle fd, ft \rangle \]
\[ \lambda \pi(f) \lambda f . \max(\pi(f)) = 100^\circ \]

\[ \text{to to} \]
\[ \lambda d' \lambda \pi(f) \lambda f . \max(\pi(f)) = d' \]

\[ \text{100}^\circ \]

By works similarly, but there is a small difference. To- and by-phrases cannot be indiscriminately adjoined.

(17) a. Mary heated the soup by 5 degrees to 100 degrees
b. *Mary heated the soup to 100 degrees by 5 degrees
This ordering can be accounted for if we make \textit{by} return something of type $⟨fd⟩$ instead of something of type $⟨ft⟩$, as below in (18).

(18) heat the soup by 5 degrees

\[
\begin{align*}
\lambda f . \ i d : d &= (\Delta(\{SC\})(f)) & \text{SPAN}(d) &= 5^\circ \\
\lambda f . \Delta(\{SC\})(f) &\rightarrow \text{vP} \langle fd \rangle \\
\text{vP} &\rightarrow \lambda f : \text{by} \langle fd, fd \rangle \\
\lambda f &\rightarrow \text{d} \rightarrow \lambda \pi fd \lambda f . \ i d : d &= (\pi(f)) & \text{SPAN}(d) &= 5^\circ \\
\langle fd, fd \rangle &\rightarrow \lambda d' \lambda \pi(fd) \lambda f : d &= (\pi(f)) & \text{SPAN}(d) &= d' \\
v \text{the soup hot} &\rightarrow \text{PP} \langle fd, fd \rangle \\
\text{vP} &\rightarrow \lambda f . \Delta(\{SC\})(f)
\end{align*}
\]

Existential closure could also do the job of \textit{to}, and we assume it does in many cases. This does the job of the pos(itive) operator of Kennedy & Levin (2008): that is, it ensures that there is change, to a certain standard—enough to count as a change, at least.

It’s likely that \textit{from} is the minimum-specifying version of \textit{to}, but there are some puzzling differences. For example, \textit{Bill heated the soup from 20 degrees} sounds somewhat odd. This may well be a hint that the measure of impelled change might better be represented as a vector instead of a degree-interval, with the minimum not being as informative as the maximum. We will let this issue lie for now.

### 3.4 In and for phrases

Here we confirm that the logical form given above in (12) for change-of-state verbs yields the correct results when combined with \textit{in} and \textit{for} adverbials. We adopt the denotations for these from Copley & Harley (2015). Only atelic predicates should be able to combine with \textit{for an hour}, and only telic predicates should be able to combine with \textit{in an hour}.

\textit{For an hour} is as in (19):

(19) \text{[for an hour] = } λs . \text{duration}(\tau(s)) = 1 \text{ hour}

This denotation takes only type \textit{st}, so right off the bat we are constrained to statives: lexical statives, aspectualized dynamic predicates (since aspect takes a type \textit{ft} argument and returns type \textit{st}) and stative readings of dynamic predicates such as generic, habitual, and futurate readings. Telic predicates such as \textit{build a house}, even when they have aspect on them, are somewhat odd unless they can be coerced into more of an atelic feeling (e.g. \#\textit{Mary was building a house for an hour} improves with the idea that she was doing some building on a house). We propose that this is because \textit{for an hour} only measures the duration of the initial situation \textit{s}, which leaves out the final situation of telics, so that it then does not really succeed in measuring the whole duration. This is not a problem with atelic predicates because they
are cases of entrainment, where the final situation takes place at the same time as the initial situation.

In an hour for Copley & Harley (2015) is as in (20):

\[ [\text{in an hour}] = \lambda f . \text{duration}(\tau(\text{init}(f))) - \text{duration}(\tau(\text{fin}(f))) = \text{an hour} \]

This denotation requires atelic predicates (launching), as desired, as it measures the duration between the beginning of the run time of \( \text{init}(f) \) and the beginning of the run time of \( \text{fin}(f) \). Atelic predicates (entrainment) are excluded because the beginning of \( \text{init}(f) \) and \( \text{fin}(f) \) happen at the same time. The denotation in (20) is certainly suggestive of a more decompositional analysis (and see Copley (2018) for a relevant overview of force-theoretic approaches to prepositions), though we will not pursue it here.

3.5 Activity verbs: null existence predicate, \( ft \) to \( e \) shift

While change-of-state verbs lexicalize a measure function that measures the difference in degrees between \( \text{init}(f) \) and \( \text{fin}(f) \), and can be telic or atelic depending on whether that difference reflects a maximal degree or not, predicates such as dance and push (the cart) that are always atelic are going to be treated differently.

Following Harley (2005) and Copley & Harley (2015), we treat roots like these as introducing entities that are created through the agent’s input of energy. In Copley & Harley (2015), for instance, we treated something like dance as referring to a dancing force in the final situation that was created through the agent’s application of force, so that there were two force arguments in the denotation: one for the agent’s force and one for the dance. Here we treat the existence of the dance, or of the push, as provided by a null existence predicate. This gives the derivation as in (21). We assume that push has a categorical scale, so that a positive degree interval represents an interval from 0 to 1. That is to say, the force f takes us from there being no push of a cart to there being a push of a cart; a little push is still a push. The tree for push the cart is in (21), showing how the cart does not participate in a homomorphism. For us, this means that the cart is not involved in providing the measure function to v, except by first composing with push. We need a type shift to shift the type \( \langle e, ft \rangle \) push to type e.
3.6 Verbs of creation and consumption; extent coercion and Predicate Restriction

We now return to homomorphisms and variable telicity, to deal with predicates of creation such as *write poetry/a poem* and predicates of consumption such as *eat soup/a bowl of soup*. In the spirit of Kardos (2012), we provide a type-shift to coerce entities into a measure function describing their extent.

(22) Extent coercion:

a. For all nodes $X$ such that $[X] \in D_e : X : \lambda s . \text{extent}(X)(s)$.

b. $\lambda X : \text{extent}(X)$ is used instead of $[X]$ when something of type $\langle \text{sd} \rangle$ is needed for the composition instead of something of type $e$.

c. Quantized entities have categorical (i.e., $\{0, 1\}$) extent scales while non-quantized entities have non-categorical extent scales.

d. We will notate extent coercion’s effect on the type of a node as “$e \Rightarrow \langle \text{sd} \rangle$”.

Relating the entity to its extent has to be done via coercion, rather than in the syntax, because of facts from *again/almost* modification which tell us there’s a difference between change-of-state verbs like *open* (which permit downstairs modification) and incremental theme verbs like the verbs of creation and consumption (which don’t). So, in (23a), the restituitive reading is possible, where someone other than Mary opened the door before. But this reading is not possible for the predicates in (23b).

(23) a. Mary opened the door again.
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b. Mary wrote a poem/ate an apple again.

This tells us that the syntax doesn’t know that the DP has been turned into an extent function in incremental theme cases, because otherwise you could modify that constituent.

So we conclude that coercion is the right option here (contra Kennedy (2012)). This ensures that a DP denoting an entity can provide the measure function to v, which in turn ensures homomorphism between the extent of the entity and the progress of the change.

One way to get the right denotation is shown in (24). This attempt uses the span function we introduced above in section 3.3 for the modification of degree arguments, as well as a POS-like operator which ensures that there is a positive degree. However, this version is syntactically implausible, as eat is too far from v to structurally combine with it.

\begin{align*}
\text{(24)} \quad \text{eat soup (version 1: preserves } \langle sd, fd \rangle \text{ type for } v, \text{ but syntactically implausible)}
\end{align*}

We could fix this problem by changing the type of v as in (25), but that is unsatisfying for the current project as it would mean these verbs alone would have a different type for v.
(25) eat soup (version 2: syntactically plausible, but requires \(\langle sd, ft\rangle\) type for \(v\))

\[
\begin{align*}
vP & \\
\langle ft\rangle & \\
\lambda f . \exists d: \text{SPAN}(\Delta(DP_d)(f)) = d & \land \text{eat}(f) \\
\lambda f . \text{eat}(f) & \\
\langle ft\rangle & \\
\lambda f . \exists d: \text{SPAN}(\Delta(DP_d)(f)) = d & \\
\lambda p_{(sd)} \lambda f . \exists d: \text{SPAN}(\Delta(p)(f)) = d & \land \text{soup}
\end{align*}
\]

And one problem with both of these is that it is not clear that \text{SPAN} should be allowed; we used it above for explicit modifiers of degree arguments but perhaps it should not make an appearance in the verb phrase.

Another possibility is to make \text{eat} type \(\langle sd, ft\rangle\) and combine it with \(v\) by Predicate Modification (Heim & Kratzer 1998). However, Rappaport Hovav (2008) and Levin and Rappaport Hovav (2010) argue, convincingly in our view, that incremental verbs denote simple properties of events (for us, forces). So we’re not willing to change the type of these roots to \(\langle sd, ft\rangle\).

What we really want is to compose something of type \(\langle ft\rangle\) (\text{eat}) with something of \(\langle fd\rangle\) (the result of composing \(v\) with the direct object). That is, we want the \(\langle ft\rangle\) function to provide a restriction on the kind of force that is fed to the \(\langle fd\rangle\) function. This seems like an eminently reasonable thing to want to do.

Perhaps the simplest way to do it is to introduce a rule that is a generalization on Predicate Modification.\(^4\) Predicate Modification (Heim & Kratzer 1998) is as follows:

\[
\text{(26) Predicate Modification: If a branching node } \alpha \text{ has as its daughters } \beta \text{ and } \gamma, \text{ and } [\beta] \text{ and } [\gamma] \text{ are both of type } \eta, t \text{ then } [\alpha] = \lambda x \in D_{\eta} . [\beta](x) \land [\gamma](x). \text{ This formula is of type } \eta, t.
\]

We then generalize on the truth value type to form a new compositional rule. We use the comma in what follows to introduce a restriction on the lambda operator.

\[
\text{(27) Predicate Restriction: If a branching node } \alpha \text{ has as its daughters } \beta \text{ and } \gamma, \text{ and } [\beta] \text{ is of type } \eta, \theta \text{ and } [\gamma] \text{ is of type } \eta, \theta \text{ then } [\alpha] = \lambda x_{\eta}, [\beta](x) \land [\gamma](x). \text{ This formula is of type } \eta, \theta.
\]

Predicate Modification can be derived from the special case of Predicate Restriction where \(\theta = t\), since \(\lambda x . [\beta](x) \land [\gamma](x)\) is truth-conditionally equivalent to \(\lambda x, [\beta](x) \cdot [\gamma](x)\).

\(^4\) Another way, we think, might go through the idea that truth values are themselves a categorical scale.
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On this version, Predicate Restriction is the semantics for the syntax of head adjunction as understood by Matushansky 2006. 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.

(28) eat soup (version 3: syntactically plausible and preserves \langle sd, fd \rangle type for v, uses Predicate Restriction)

\[
\begin{array}{c}
vP \langle fd \rangle \\
\lambda f, eat(f) . \Delta^{(\text{DP})}(f)
\end{array}
\]

\[
\begin{array}{c}
\langle ft \rangle \\
\lambda f . eat(f)
\end{array}
\]

\[
\begin{array}{c}
vP \langle fd \rangle \\
\lambda f . \Delta^{(\text{DP})}(f)
\end{array}
\]

\[
\begin{array}{c}
\langle sd, fd \rangle \\
\lambda p_{(sd)} \lambda f . (\Delta(p)(f))
\end{array}
\]

the soup

\[
\lambda p_{(sd)} \lambda f . (\Delta(p)(f))
\]

\[
\lambda p_{(sd)} \lambda f . (\Delta(p)(f))
\]

\[
\lambda p_{(sd)} \lambda f . (\Delta(p)(f))
\]

\[
\lambda p_{(sd)} \lambda f . (\Delta(p)(f))
\]

\[
\lambda p_{(sd)} \lambda f . (\Delta(p)(f))
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\[
\lambda p_{(sd)} \lambda f . (\Delta(p)(f))
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\[
\lambda p_{(sd)} \lambda f . (\Delta(p)(f))
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\[
\lambda p_{(sd)} \lambda f . (\Delta(p)(f))
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\[
\lambda p_{(sd)} \lambda f . (\Delta(p)(f))
\]

\[
\lambda p_{(sd)} \lambda f . (\Delta(p)(f))
\]

\[
\lambda p_{(sd)} \lambda f . (\Delta(p)(f))
\]

3.7 Other incremental theme verbs

Although version 3 works for verbs of creation and consumption, it will not work for incremental theme verbs that are not verbs of creation or consumption, such as mow and read. The reason is that version 3 uses extent coercion, and that means that the measure of impelled change has to measure a change in extent of the incremental theme. But incremental theme verbs that are not creation or consumption verbs do not involve a change in extent of the object. If you mow the lawn, for example, what changes is the extent of mowed lawn, not the extent of the lawn. So, the verb itself as well as has to be involved in the type \langle sd \rangle measure function.

How could this be accounted for? We will not be able to account for it here, but one clue is given by the fact that while degree achievements allow by phrases, as in (29), incremental theme verbs do not, as in (30):

(29) 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

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

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 (solid-underlined) degree-interval, not the (dotted-underlined) degree-instants that are its endpoints. This is effectively what

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is wrong with all of the examples in (30): in each one, the apparent entity-denoting DP is actually something that saturates or existentially closes the degree-interval of change itself, so there is no room for a by-phrase, which would otherwise be a predicate of that degree-interval.\(^5\)

That, in fact, is plausibly why one can have explicit degree-interval-denoting objects for these verbs, as in (31):

(31) a. eat three spoonfuls of the soup  
b. mow three square meters of the lawn  
c. read five pages of the book  
d. walk sixteen miles of the Appalachian Trail

Conversely, the cases which do permit degree-specifying by-phrases, cannot see their object DPs replaced with measure-DPs:

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

In effect, these verbs require a small clause and the incremental theme verbs in (31) do not; the small clause is a predicate of degree-intervals, and the object of the incremental theme verbs saturates or binds degree-intervals.

3.8 Verbs of maintaining

An advantage of a force-theoretic approach to verbal predicates is the account for verbs of maintaining such as stay, keep, endure, preserve, and maintain. The idea pursued in Copley & Harley (2015) is that verbs of maintaining denote a force whose init(\(f\)) and fin(\(f\)) are both described by the relevant predicate—i.e. a force which ensures that that the truth value of that predicate does not change from init(\(f\)) to fin(\(f\)).

We propose that stay is like eat in being essentially a manner that is structurally introduced using the Matushansky derivation for head adjunction (this differs from Copley & Harley (2015), where we proposed that stay was a flavor of v). Thus, like eat, stay composes with v by way of Predicate Restriction. The restriction that stay contributes is that the initial situation of the force and the final situation of the force are the same.

\[
[\text{stay}] = \lambda f . \ fin(f) = \ init(f)
\]

The denotation in (33) may seem like too strong a restriction. It seems to entail that if something irrelevant changes, even if it would otherwise count as a staying, it does not count as a staying. However, this is the only option for stay that we can see. We cannot do as we did in Copley & Harley (2015) and say that only the relevant property \(p\) changes on the way from init(\(f\)) to fin(\(f\)), because now stay is too high to have access to \(p\). Could it nonetheless be the right denotation?

\(^5\) This would be entirely parallel to how by-phrases introduce agents in the passive, but are impossible with active Voice.
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We could treat the situations as quite thin situations, i.e., only including the staying entity and the staying location, and thereby exclude anything irrelevant. The situations could equally be quite thick ones, and include other entities. Suppose they are. However, even in this case, we think the denotation in (33) excludes the scenario of irrelevant things happening, for this reason. It’s certainly possible to imagine something irrelevant happening at the same time as a staying, but it’s not possible to include something, say, in init(f) but not in fin(f), since init(f) and fin(f) must be the same.

Here’s another try to discredit (33): suppose Mary and John are in a room. John is staying in the room, but Mary is just there. In this case, couldn’t we truly say that Mary is staying in the room, on the basis of the force that is keeping John there? This argument goes through. So, in order for (33) to work for stay, situations should be thin.

A reason to like (33) is that it on its own gets us the presupposition for stay that we had to stipulate in Copley & Harley (2015). Consider the tree for stay there, in (34):

Recall that degrees are eventually existentially closed off by existential closure (not shown in this tree). This entails there is a degree to which the entity is there in both init(f) and fin(f). We have to be a little tricky to get p’s being true in fin(f) to be the assertion and p’s being true in init(f) to be the presupposition, but given that fin(f) is defined on the basis of init(f), so is in a sense newer information, we think this is plausible (and potentially interesting).

4 Conclusion

In this paper, we have hypothesized a unified denotation for dynamic v based on a framework that includes both degrees and forces. The idea is that there is a basic meaning of verbs,
encapsulated in the hypothesized denotation of \( v \), in which a force (an input of energy) provokes a change (perhaps zero) along a degree scale. The goal is for the syntax-semantics interface of the verb phrase to be no more than type theory and compositional rules. Where verbal predicates have differing properties, we argued that they should follow from compositional considerations. We investigated change-of-state verbs, activities, verbs of creation and consumption, and verbs of maintaining; the tweaks needed were a null existence predicate, a couple of type shifts, a generalization of Predicate Modification and an assumption that situations are thin. Incremental theme verbs that are not creation or consumption verbs (\textit{mow, read}) presented a different picture, which we will investigate in the next version of this paper.

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